

S Final technical
628.1 memorandum, Silver
6832 Bow Creek RI/FS
M26strd
1989

SILVER BOW CREEK INVESTIGATION

FINAL TECHNICAL MEMORANDUM
SILVER BOW CREEK RI/FS

STARS :
TAILINGS RANKING & DATA ANALYSIS
OF SILVER BOW CREEK WASTE



PLEASE RETURN

CHM HILL

4c

May 13, 1991
Nov 18, 1992
Apr 2, 1993
Jun 23, 1993
Sep 18, 1993

MONTANA STATE LIBRARY
S 628.16832 M26strd 1989 c.1
Final technical memorandum, Silver Bow C



3 0864 00063611 1



STATE DOCUMENTS COLLECTION

JAN 25 1990

MONTANA STATE LIBRARY
1515 E. 6th AVE.
HELENA, MONTANA 59620

FINAL TECHNICAL MEMORANDUM
SILVER BOW CREEK RI/FS

STARS :
TAILINGS RANKING & DATA ANALYSIS
OF SILVER BOW CREEK WASTE

Submitted to:

MDHES
Helena, MT

Submitted by:

Schafer and Associates
P.O. Box 6186
Bozeman, MT

Montana State University
Reclamation Research Unit
Bozeman, MT

CH2M Hill
1610 B Street
Helena, MT

Date
February 10, 1989

Copy 3 of 30

MAY 15 1991

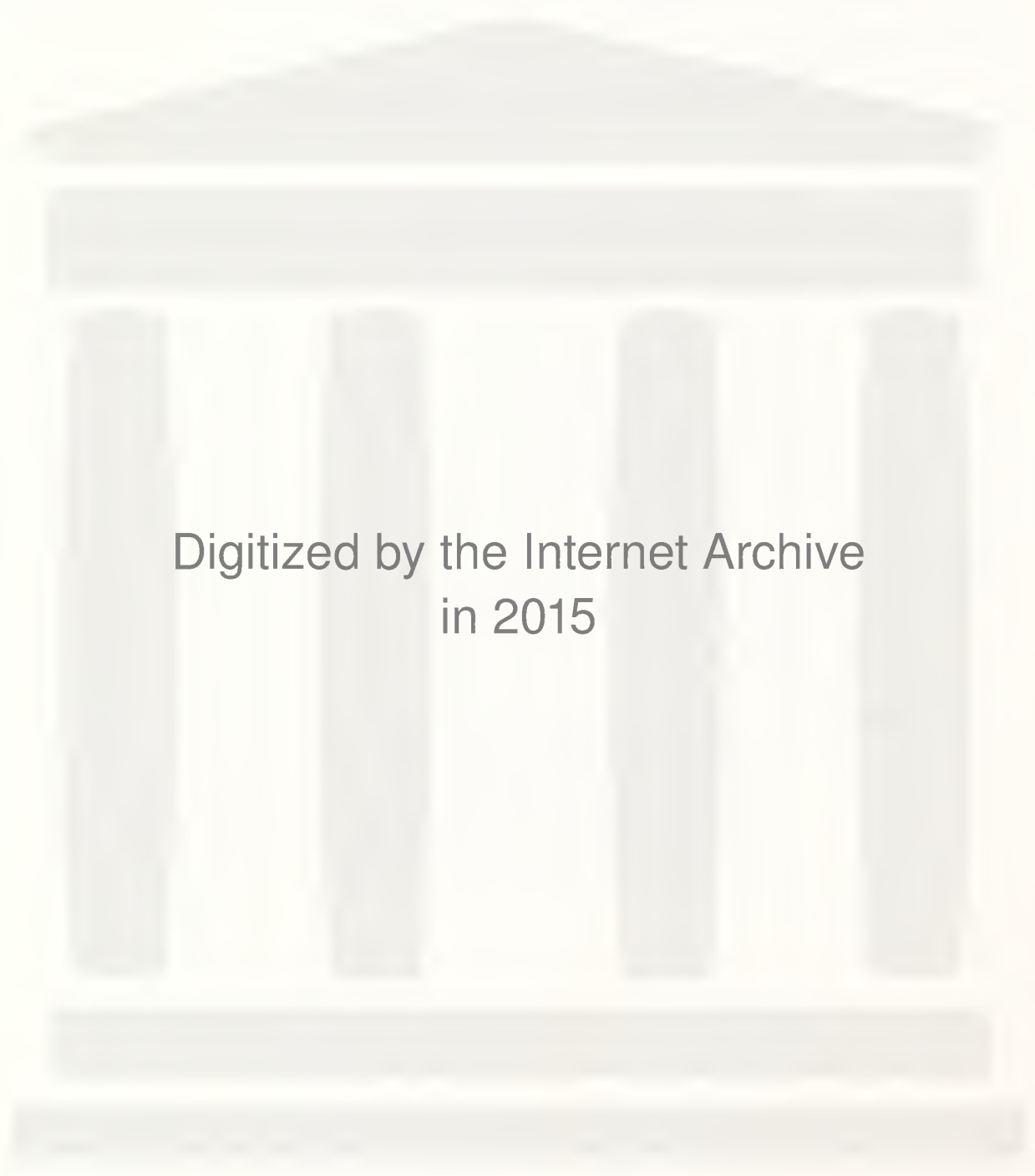
MAY 15 1991

MAY 15 1991

June 23, 1993

Sept 15, 1993

SECTION	DESCRIPTION	CONTENTS	PAGE
	CONTENTS		ii
	EXECUTIVE SUMMARY		1
1.0	BACKGROUND		2
1.1	Site History.....		2
1.2	Streamside Tailings Operable Unit.....		5
2.0	OVERVIEW.....		7
2.1	Waste Ranking Procedure.....		7
2.2	Multivariate Statistics.....		7
3.0	STATISTICAL APPROACH.....		9
3.1	Review and Screening of Data.....		11
3.2	Data Encoding.....		14
3.3	Normality of Data.....		14
3.4	Multiple Regression Analysis.....		14
3.5	Screening Variables.....		18
3.6	Classification.....		19
3.7	Data Discrimination.....		20
3.8	Numerical Model Testing.....		22
4.0	SILVER BOW CREEK ANALYSIS.....		26
4.1	Waste Ranking Summary.....		26
4.2	Use of Waste Ranking System.....		28
4.3	Conclusions.....		28
	APPENDIX A-Data Summary Tables.....		29
	B-Data Normality/Z Scores.....		48
	C-SAS PRINCOMP Procedure.....		54
	D-SAS Average Linkage Cluster Method.		57
	E-SAS Canonical Discriminant Analysis		60
	F-Estimating Soil Texture.....		66



Digitized by the Internet Archive
in 2015

<https://archive.org/details/finaltechnicalme1989mont>

EXECUTIVE SUMMARY

An investigation is underway to develop low-cost innovative remedial measures for extensive mine waste deposits found within the Silver Bow Creek CERCLA site. The purpose of the Streambank Tailings and Revegetation Study (STARS) is to design remedial measures which use soil amendments and revegetation to abate metal flux from streambank tailings, contaminated soils, and tailings impoundments. Remedial measures will be designed for each distinct "type" of contaminant found along Silver Bow Creek.

This statistical data analysis was performed in support of the STARS investigation. The primary objectives addressed by this deliverable were:

- 1) to identify different classes of streambank wastes, tailings, and contaminated soil materials from the Silver Bow Creek CERCLA site,
- 2) to group wastes which require similar remedial clean-up methods, and
- 3) to develop a waste material classification method based on field measured parameters.

Wastes from the Silver Bow Creek site can be successfully discriminated using field-measured parameters. Numerical grouping of Silver Bow Creek streambank wastes have distinguished three classes of materials. Class 1 is very sandy and has moderate levels of pH and EC, type 2 which has an abundance of coarse-fragments, and has low pH and low EC. Class 3 is silty and has the highest pH and highest EC of the waste types. Chemical characteristics differ between classes. Six types of contaminated soil media are needed to represent the Silver Bow Creek materials including class 1 through 3 streambank tailings, buried soil materials, flood-affected soil materials, and intact tailings pond wastes.

1.0 BACKGROUND

1.1 Site History

Silver Bow Creek originates on the western slope of the Continental Divide north of the City of Butte, Montana. It drains approximately 425 square miles before its confluence with Warm Springs Creek, forming the Clark Fork River (Figure 1).

The history of mining in the Butte area began with the discovery of placer gold in Silver Bow Creek in late summer of 1864. Various mining operations for several precious and semi-precious metals and minerals have continued through today.

More than 100 years of continuous mining and related activities have greatly changed the area's natural environment. Early mining, milling, and smelting wastes were dumped adjacent to, and directly into, Silver Bow Creek and transported downstream to the Clark Fork River. In 1911, Anaconda Company built the first treatment pond near Warm Springs, Montana, to settle out wastes from Silver Bow Creek before the water was allowed to flow downstream. In 1916 and in 1959, two more treatment ponds began operation. Silver Bow Creek continued to be affected by raw mining and milling waste until 1972, when a treatment plant was added to the Weed concentrator in Butte. Creek contamination problems were compounded by urban and domestic sewage and refuse from wood products treatment plants, phosphate and manganese production facilities, and chemical factories. Mill tailings and other mining wastes in and near the creek contribute to downstream contamination, particularly from potentially toxic metals including arsenic, cadmium, copper, lead, iron, and zinc. These elements and others were present in the mine ore and remain in the environment as by-products of the mining and smelting processes.

In 1983, the U.S. Environmental Protection Agency (USEPA) designated Silver Bow Creek, contiguous portions of the upper Clark Fork River, and their environments as a high priority Superfund cleanup site. The Solid and Hazardous Waste Bureau (SHWB) of the Montana Department of Health and Environmental Sciences (MDHES) administered the USEPA appropriations to conduct a Remedial Investigation (RI) of the Silver Bow Creek (SBC) drainage.

The SBC RI consisted of coordinated individual studies to develop data on the nature, extent, and severity of contamination within the site. SBC RI Phase I field work was completed in January 1986; MultiTech reported results of the studies in several reports in 1986-1987. A summary Final Report discusses the entire project; final reports for each individual study were also prepared and issued as appendices to the Summary.

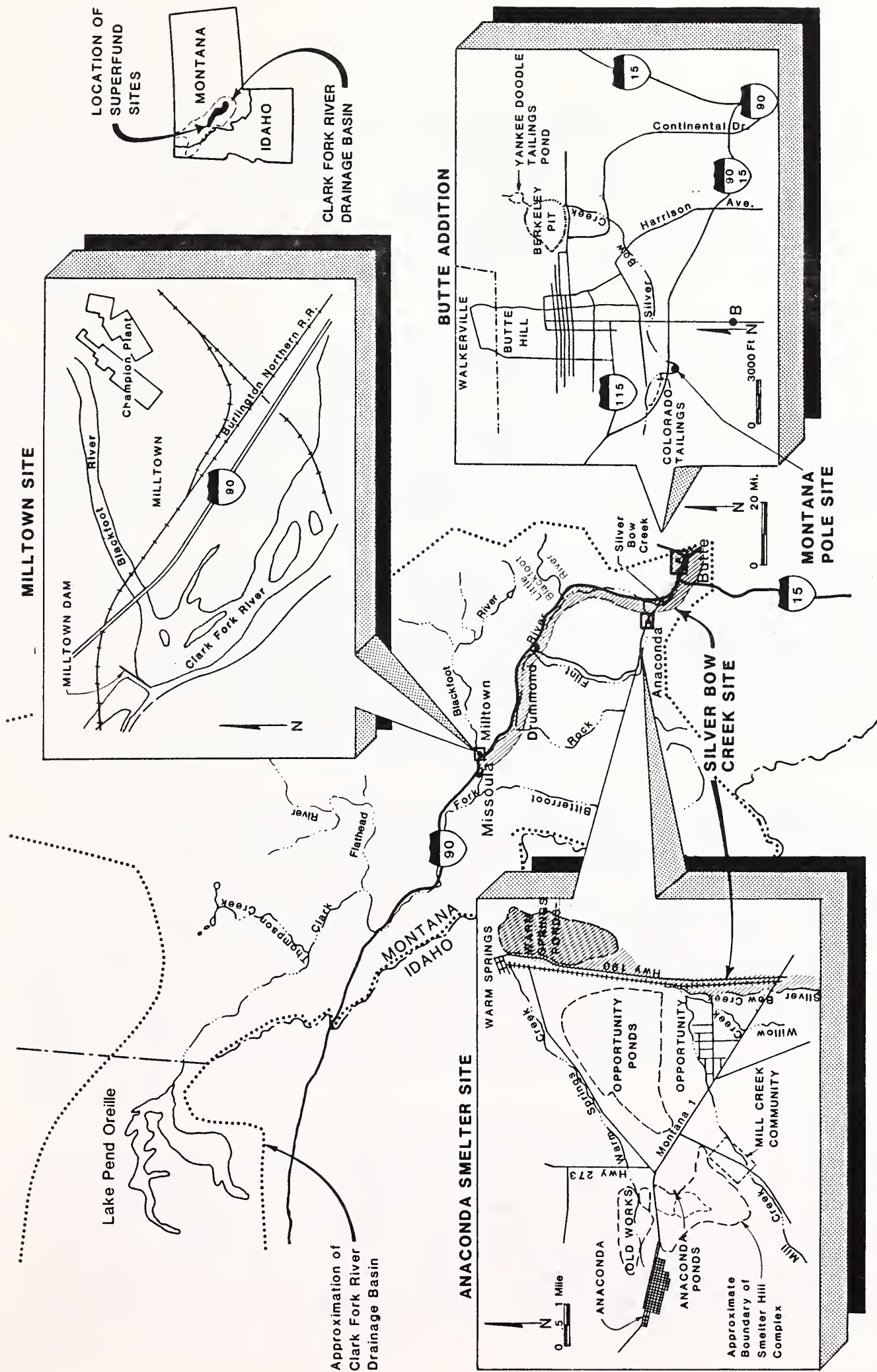


Figure 1.1 Location of Superfund sites in the upper Clark Fork River.

The history of man's activities along Silver Bow Creek is long and varied. The first record of any disturbance of the stream's natural channel is in 1864 when placer mining commenced along Silver Bow Creek (Meinzer, 1914; Freeman, 1900; Smith, 1952). Placer mining was used to extract low-grade gold deposits along Silver Bow Creek and its tributaries. The majority of placer operations in the area had ceased by 1869, although a small contingent of miners continued to placer mine local streams.

Concurrent with placer mining along Silver Bow Creek, hard rock mining started on mineralized veins outcropping on Butte Hill, north of Silver Bow Creek. Several small smelters/concentrators and a wet-process quartz mill, the Davis Mill, were built between 1866 and 1868 along Silver Bow Creek to process ore (Smith, 1952). Although some copper and silver were being produced, all facilities were closed by 1869. Apparently, little mining activity occurred in the Butte area from 1869 to 1874.

William Farlin re-staked some mining claims on the Butte Hill in 1875 as a result of favorable assays of silver ore found in the area (Smith, 1952). This rejuvenated mining activity in Butte, and by 1878 several small smelters were operating in the area. Between 1879 and 1885, at least six major smelters were built along Silver Bow Creek from Meaderville to Williamsburg (Historical Research Associates (HRA), 1983; Smith, 1952; Meinzer, 1914; Freeman, 1900). A smelter was also constructed at the new town of Anaconda in 1884 (Smith, 1952).

The major smelters constructed along Silver Bow Creek operated nearly continuously until 1910 (HRA, 1983). By 1910, Anaconda Copper Mining Company (ACM) had purchased and closed all but one of the major concentrator/smelters (the Pittsmont) located adjacent to Silver Bow Creek; most of the ore was shipped to the smelter in Anaconda for processing. This practice continued until 1980 when the smelter in Anaconda was closed. The Pittsmont Smelter operated until 1930. The Timber Butte Mill, located south of Silver Bow Creek, also operated until approximately 1930. Tailings from the Timber Butte Mill, Butte and Superior, and East Butte concentrators were sluiced in various amounts to tributaries of Silver Bow Creek until at least 1918 (Flynn, 1937).

Large-scale underground mining continued in Butte during the early- to mid -1900s. In 1955, ACM commenced open-pit mining at the Berkeley Pit. Low-grade copper ore mined from the Berkeley Pit was processed at the Weed Concentrator in Butte, constructed in 1963. Silver Bow Creek continued to receive raw mining and milling wastes until 1972, when a treatment plant was added to the Weed Concentrator. In 1977, ACM became a subsidiary of Atlantic Richfield Company (ARCO). The subsidiary's name was changed at this time to Anaconda Minerals Company (AMC). ARCO

closed all underground mining operations in Butte in 1980 because of a depressed copper market. ARCO then closed the Berkeley Pit in 1982 and the adjacent East Berkeley Pit in 1983. The underground mines beneath Butte and the Berkeley Pit were allowed to flood, and water levels in the area are currently rising in response to the cessation of pumping.

In 1986, Montana Resources Inc. (MRI) purchased Anaconda's Butte Operations (including the East Berkeley Pit, Continental East Pit, and Yankee Doodle Tailings Ponds). MRI is currently mining copper ore from the East Berkeley Pit and processing mined ore in the Weed Concentrator. There are currently no direct discharges from MRI's operations to Silver Bow Creek.

Silver Bow Creek and contiguous portions of the upper Clark Fork River were listed as a Superfund site in 1983 by the U.S. Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). The site extends from Butte to Milltown, Montana, some 140 river-miles. The MDHES administers EPA appropriations and directs the efforts to conduct remedial investigation/feasibility study (RI/FS) activities associated with the site.

In order to facilitate the RI/FS process, the Silver Bow Creek site has been divided into the following operable units (OUs):

1. Area I (Butte)
2. Streamside tailings
3. Agricultural lands
4. Warm Springs treatment ponds

Each of these OUs will proceed through the RI/FS process independently, but during the FS the evaluation of the effectiveness of a given alternative will have to be based on the entire Silver Bow Creek site and not just the OU that is being considered.

1.2 Streamside Tailings Operable Unit

The streambank tailings and revegetation study (STARS) has been initiated to develop low-cost innovative remedial measures for potential clean-up of portions of the streambank tailings operable unit.

Contamination of air, soil, surface and ground water is derived primarily from tailings and other mining waste deposited in the Silver Bow Creek channel and floodplain. Several million yards of mining waste are found in the floodplain of Silver Bow Creek. Remediation of these wastes is the focus of RI/FS

activities on the Streambank Tailings operable unit of the Silver Bow Creek investigation. Streambank tailings are situated so that they are eroded by wind or water. Sulfide oxidation in the mine wastes increases acidity which in turn causes most metals to be more mobile. As water percolates through or flows across the barren streambank mine wastes, metals are leached into surface water and groundwater. Evaporation of water from the land surface leaves a residue of metal-enriched salts which can be degrade air quality. Typical levels of metals in tailings are shown in Table 1.1.

Remedial measures developed for streambank tailings will strive to limit metal mobility. Streamside tailings deposits are variable in chemical and physical properties. Hence, revegetation efforts must be adapted to different "types" of tailings in order to be successful. The objective of this report is to identify and define the kinds of tailings found in the project area.

Table 1.1. Typical concentrations of contaminants in mine wastes situated along Silver Bow Creek.*

PARAMETER	ARITHMETIC MEAN	MAXIMUM VALUE
pH	3.97	2.3 (lowest)
EC (micromhos/cm)	3440.	7700.
Sand (%)	62.2	90
Silt (%)	25.7	68.1
Clay (%)	12.1	30.4
	GEOMETRIC MEAN	MAXIMUM VALUE
	----- (mg/kg soil) -----	-----
Copper	1,410	11,200
Zinc	2,140	22,000
Lead	912	6,477
Cadmium	11.2	108
Arsenic	347	3,140
Manganese	977	13,300
Chromium	10.7	142
Mercury	5	61

* Data were taken from initial characterization of 35 bulk mine waste samples collected for STARS, Phase I.

2.0 OVERVIEW

This investigation utilizes multivariate statistical procedures to classify and predict contamination occurring within the Silver Bow Creek CERCLA site in southwestern Montana (Figure 1.1). Contamination at this site includes soils damaged by flooding of waste-laden water, contaminated buried soils, and fluvial deposits of mixed mine waste consisting of tailings, waste rock. Current reclamation studies of the Silver Bow Creek site are testing methods of optimum in-situ remediation of the various types of contamination. The goal of tailoring remedial measures to specific sites over a large area requires a reliable and cost-effective means of site classification. The methods and results presented in this technical memorandum summarize the statistical analysis of the Silver Bow Creek streambank tailings.

2.1 Waste Ranking Procedure

The statistical method derived for this investigation utilizes previously collected (Multitech, 1987) physical and chemical data to classify and predict important types of waste materials based on easily-measured, observable field parameters such as pH, electrical conductivity (EC), sand, silt, and coarse-fragment content. The use of field parameters reduces the need for costly and time consuming laboratory analysis. The classifications have been tested using an independent data set consisting of analyses performed on 35 waste samples collected subsequent to the development of the waste ranking system.

To meet project objectives, classes of waste material should be differentiated on the basis of texture, pH, and EC. Each designated class should have unique remediation requirements and should be distinguishable in the field. Detailed descriptions and interpretation of the assigned classifications are given in Section 3.

2.2 Multivariate Statistics

The classification method developed for this study utilizes multivariate statistical procedures which provide a system for analysis of data sets that include several variables exhibiting varying degrees of multiple correlation. Multivariate statistics allow an analysis of groups of variables in combination for large numbers of samples.

Variables represent values of specific properties that can change from observation to observation. Variables can be divided into two major types - independent and dependent variables. Independent variables are known or measured quantities that determine or predict the value of other variables which are

termed dependent variables. In most cases, a set of one or more independent variables will predict a single dependent variable. Dependent variables can be considered the output variables and independent variables the input. Using multivariate statistics, multiple dependent and independent variables can be analyzed simultaneously.

Several multivariate procedures exist that allow for the manipulation, segregation, classification, prediction, and discrimination of data sets. The following section outlines the various procedures used for the analysis of the Silver Bow Creek RI/FS data set.

3.0 STATISTICAL APPROACH

Due to the varying analytical methods and volume of data collected as part of this RI/FS project, statistical methods were required to organize, classify, and compare data obtained from the site. A simplified numerical classification of waste materials using parameters readily measured in the field was sought so that waste material classifications, reflecting required remediation, could be determined during subsequent field investigations. This approach was intended to reduce the need for analytical laboratory determinations of material properties during site clean-up. Wastes have been classified from the Silver Bow Creek site using the following approach:

- o Review and screen raw data.
- o Enter data into a computer data base.
- o Normalize data, as required.
- o Identify field variables that correlate with laboratory-measured analytical variables.
- o Select those variables that best describe the variability of data.
- o Using selected variables, group the samples into internally consistent classes .
- o Numerically define the class limits discriminated in the previous step.
- o Test the numerical classification with an independent data set.

Analytical data from the following sources were utilized for this analysis.

- o Multitech (1986) Silver Bow Creek RI report, Appendix B: Ground Water and Tailings Investigation (46 tailings samples).
- o EPA contract lab program total metals RAS case number 8759 and SAS case number 3538-H. (35 bulk samples of waste collected 11/87, contract compliance, validation, and QA statements completed).

The procedures used for each task are discussed in the following sub-sections. Discussion requiring some degree of familiarity with statistical procedures is set with smaller type face and is slightly inset. The inset material should provide the

reader familiar with statistical procedures a general explanation of the methodology. By skipping over the inset material, readers who are unfamiliar with multivariate statistics should be able to gain a concept of the general theme behind each analysis. This document is not intended as an introduction to multivariate statistics. The reader that is interested in pursuing a deeper understanding of the methods employed in this analysis is referred to the following texts:

Statistical Methods, Snedecor and Cochran, 1978, Iowa State University Press

Using Multivariate Statistics, Tabachnik and Fidell, 1983, Harper and Row

Multivariate Data Analysis, Cooley and Lohnes, 1971, John Wiley and Sons

Classification, Gordon, 1981, Chapman and Hall

SAS Users Guide: Statistics, Version 5 Edition, 1985, SAS Institute

3.1 Review and Screening of Data

Data presented for the Silver Bow Creek RI/FS were initially screened to select data sets with the following analyses: 1) texture 2) pH 3) electrical conductivity and 4) sulfur content (total, pyritic, or sulfate). These parameters were expected to have the most influence on the selection of remedial measures based on previous investigations.

Initially only actual mine waste materials were classified in this investigation. Other contaminated soil media were excluded since they are expected to be less challenging to remediate. The degree of contamination of natural soils is not expected to be readily determined from field observations. Assessment of native soil contamination is more closely related to depth of burial, proximity to Silver Bow Creek, and distribution of historical irrigation systems.

The data sources selected for analysis included the Multitech Phase I RI data from Silver Bow Creek (46 observations). Additional data collected by Hydrometrics (37 samples) was found to lack suitable texture data (inadequate measurement of coarse fragment content) and could not be used. Data from 35 bulk samples collected as part of the phase 1 STARS investigation were used to validate the ranking system developed with the phase 1 RI data.

The soils data from both the phase 1 and STARS bulk samples is tabulated in Appendix A. A map of sample locations for the phase 1 RI samples is shown in Figure 3.1. Sample location for the STARS bulk samples is shown in Figure 3.2.

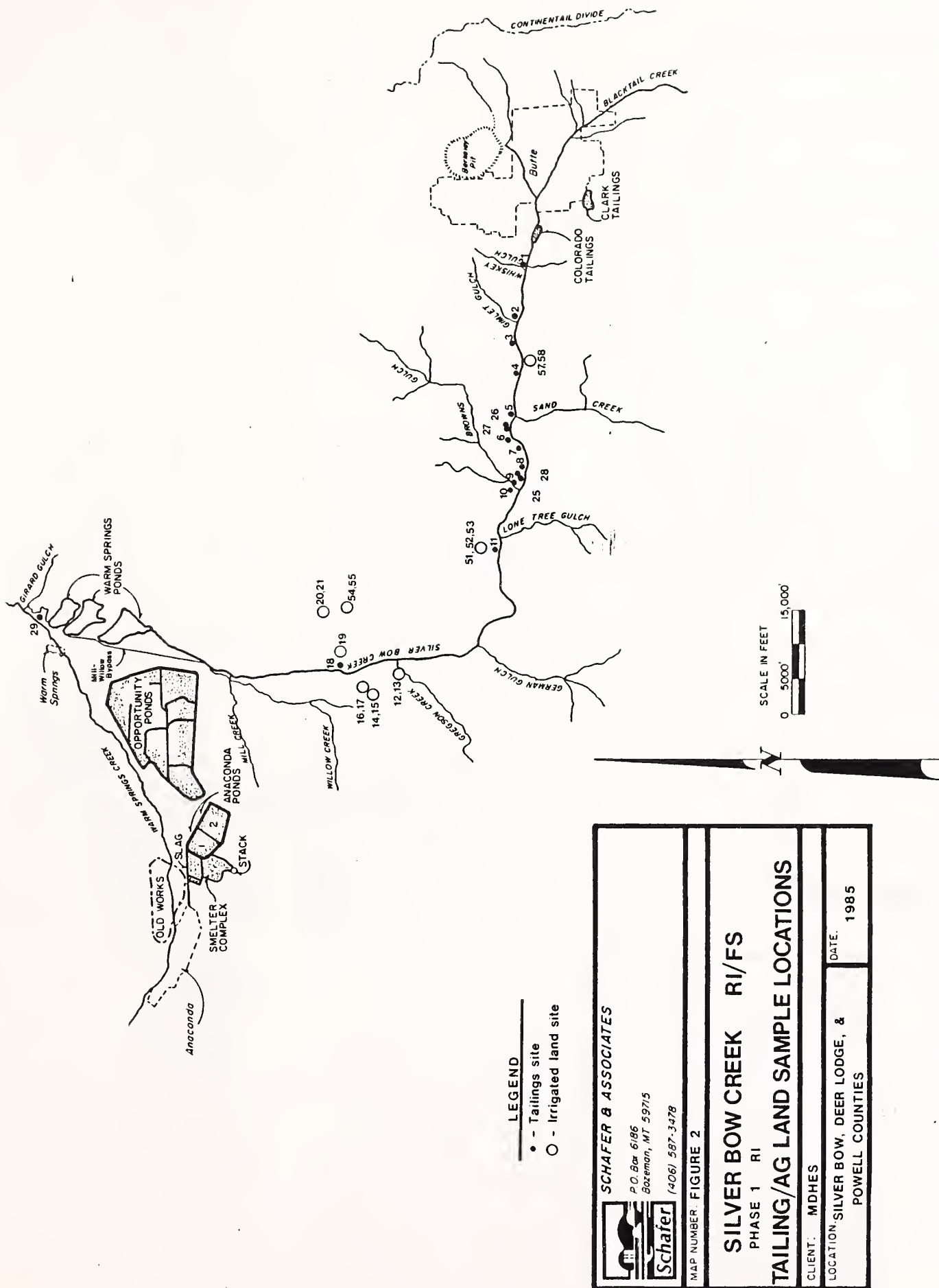


Figure 3.1. Location of samples from the Phase 1 RI - Silver Bow Creek site.

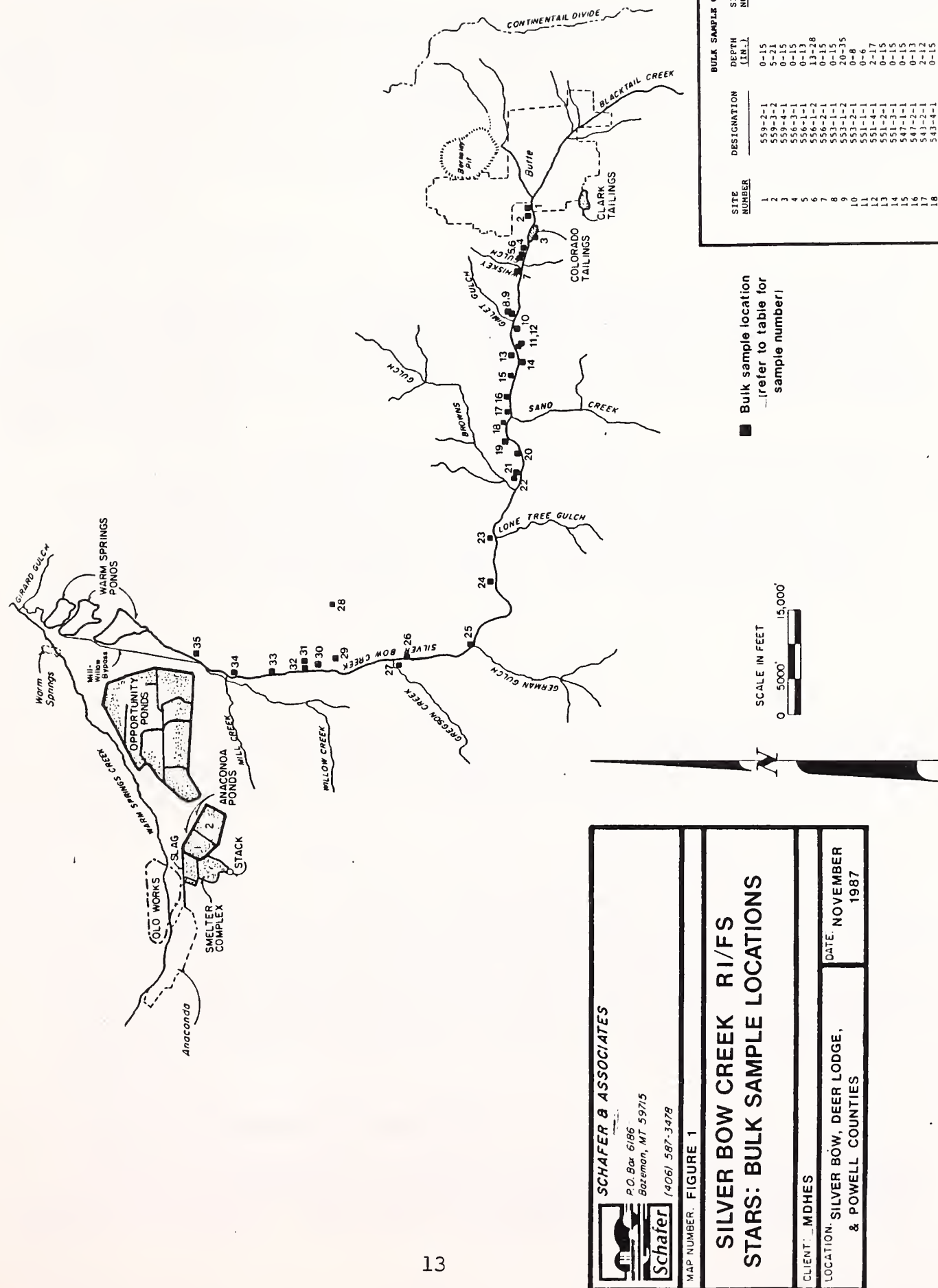


Figure 3.2. Location of 35 STARS bulk samples from the Silver Bow Creek site.

3.2 Data Encoding

Data that were selected in the first step, were then entered into a structured microcomputer data base (using dBase III Plus, Ashton-Tate). The data base was structured to contain entire analytical reports in a manageable format. The similar data base structure and available programming language facilitated creation of files for statistical analysis, and for transformation of data. Addition of key codes and classifying fields into the data base allowed observations to be sorted or used selectively for data analysis.

3.3 Normality of Data

Data normality is required for some multivariate procedures. A normal distribution is completely determined by the mean and standard deviation of the sample population and has a typical bell-shaped curve. This curve is used to predict the percentage of a sample population that has a specific value or range over a tested parameter.

The general bell-shaped curve of the normal distribution has its highest point at the mean value (μ) of the population. Over two-thirds of the population are valued within the interval $\mu \pm s$, where s is the standard deviation of the population. The normal distribution can be transformed (or standardized) to what is termed the Z scale of the population so that $\mu=0$ and $s=1$. The rescaled measurement is given by where Z is

$$Z = \frac{x - \mu}{s} \quad \text{Equation 2.1}$$

variously termed the "standard normal variate", or the "normal variate in standard measure" (Snedecor & Cochran, 1978). Transformation from the Z scale back to the X scale of original values employs the following formula

$$X = Zs + \mu \quad \text{Equation 2.2}$$

Equation 2.2 is a linear equation so that data normality can be viewed graphically by plotting Z score against X value. Values reported for individual parameters in the Silver Bow Creek data set were checked for normality using this procedure. Data not showing normal characteristics (straight line plots) were logarithmically transformed to approximate a normal distribution. The Z score graphics for selected parameters and quantitative analyses of data normality are given in Appendix B.

3.4 Multiple Regression Analysis

Multiple regression analysis is used for several different applications where data prediction, correlation, or correlation ranking is sought. The result of applying multiple regression

techniques to a data set is an equation that can be used to predict a dependent variable from a linear combination of independent variables. For example, the percentage of rock, sand, iron, and lead (independent variables) may predict sulfur content (dependent variable) when considered together using a hypothetical data set.

A linear equation from a regression analysis will have the form

$$Y = t + b_1 x_1 + b_2 x_2 + \dots + b_k x_k + e' \quad \text{Equation 2.3}$$

where Y is the predicted value of the dependent variable, t is a translation (or scaling) constant, and $x_1, x_2, \dots, x_k$ represent independent variables from the data set. The constants $b_1, b_2, \dots, b_k$ are termed the partial regression coefficients and represent the expected change in Y when the corresponding x_n variable increases by 1 unit while all other x_n 's remain unchanged. The value of e' represents the residual or that part of Y that is independent of $x_1, x_2, \dots, x_k$.

Using the hypothetical data set mentioned earlier Y would represent the predicted sulfur content and x could be the percentage of rock, x_2 - the percentage of sand, x_3 - the iron content, and x_s could represent the lead content. Then b_1 would represent the relative importance or "weight" of the rock value to the prediction, b_2 for sand, and so on. The e' value then represents the effect of variables other than rock, sand, iron, and lead on the predicted value of sulfur. Finally, the t term simply shifts the line described by the equation to the proper position within the $x_n - Y$ coordinate space.

The derivation of regression equations can be studied in any one of several statistical texts such as Snedecor and Cochran, 1978 or Tabachnick and Fidell, 1983.

Normalized values for parameters from the Silver Bow Creek data set were subjected to a multiple regression analysis. The objective of this step was to determine the predictability of metal levels using field and simple laboratory observations. Table 3.1 contains a listing of the dependent and independent variables that were used.

Table 3.1. Dependent and independent variables used in the multiple linear regression analysis.

Extract	Element									
Dependent Variables:										
<u>Soluble</u> (Saturation Extract)	Cu	Cd	Mn	Zn	As	P				
<u>Plant-Available</u> (NH4OAc Extract)	Cu	Cd	Mn	Zn	Fe	Pb				
<u>Total</u> (HNO3/H2O2 Extract)	Cu	Cd	Mn	Zn	Fe	Pb	S	As	SO4	
<u>Pyritic</u>	S									
Independent Variables:										
<u>Texture (%)</u>	Sand, Silt, Clay, Rock									
<u>Color</u>	Moist Value, Moist Chroma									
<u>Chemical Parameters</u>	SO4, pH, EC, & Total S									
<u>Other Parameters</u>	Moist Consistence, Depth									

Multiple regression analyses were conducted by assigning all field properties to be independent variables which were all used to predict a single dependent variable (like soluble copper for example). Then the contribution of each independent variable to the overall regression was reviewed. If the contribution was not statistically significant, then that independent variable was rejected and the regression was re-run using the remaining independent variables. This "step-wise" removal of variables insures that only those independent variables that correlate with the dependent variable in a statistically significant manner are used in the regression.

Table 3.2 illustrates the equations that were derived from the multiple regression procedure. The R^2 values listed in the Table represent the squared multiple correlation values for each regression equation. The squared multiple correlation value represents the proportion of variation in the dependent variable (predicted parameter) that is predictable using the optimum linear combination of independent variables (field and simple lab observations) (Tabachnick & Fidell, 1983). Using the R^2

Table 3.2. Predictive equations developed through multiple linear regression analysis of selected dependent and independent variables.

Dependent Variable	R ²	Intercept	Predictive Equation			
<u>Soluble (Saturation Extractable)</u>						
Cu	0.79	1.19	-.0160(R)	+ .9726(SO4)	- .651(pH)	
Cd	0.81	-1.63	-.0151(R)	+ .0222(D)	+ .376(SO4)	
Mn	0.68	3.93	-.0199(S)	+ .0328(D)	- .592(pH)	+ .0000639(EC) - .148(MC) + .229(ST)
Zn	0.77	1.12	-.0245(R)	+ .0303(D)	+ .905(SO4)	+ .000137(EC) - .607(pH)
<u>Plant-Available (NH4OAc Extractable)</u>						
Cu	0.42	.249	-.311(MV)	+ .369(SO4)	+ .617(TS)	
Cd	0.70	-.479	.00095(S)	- .0114(R)	+ .0148(D)	+ .00004(EC)
Mn	0.62	.763	.0224(SI)	+ .0001(EC)		
Zn	0.70	1.127	.0178(SI)	- .0084(R)	+ .0159(D)	+ .3244(SO4) - .1271(PH)
Fe	0.83	2.865	-.0076(S)	- .0289(C)	+ .1673(MCH)	- .4400(PH) + .00006(EC)
Pb	0.47	5.272	-.0433(S)	- .1020(C)	+ .0303(R)	- .2803(MCH) - .00007(EC)
<u>Total (HNO3/H2O2 Extractable)</u>						
NO CORRELATION						
Cu	0.76	.6711	-.0206(R)	+ .0694(MCH)	+ .0100(D)	+ .00002(EC) + .5169(MC)
Cd	0.89	.0329	.0297(S)	+ .0185(SI)	- .0309(R)	+ .0117(D)
Mn	0.34	3.755	-.0387(R)			
Zn	0.39	.6189	-.3546(MCH)	- .0515(D)		
Fe	0.68	-1.854	.0489(S)	+ .0452(SI)	- .2018(pH)	+ .7758(MC)
<u>Sulfur, arsenic, and phosphorus</u>						
Total S	0.41	2.584	-.0313(C)	- .0206(D)	+ .5047(SO4)	
Pyritic S	0.73	1.038	-.0203(C)	- .0817(pH)	+ .7767(TS)	
Total S -						
Sulfate S	0.62	2.059	.0885(MCH)	+ .0197(D)	+ .00013(EC)	
Soluble As	0.62	409.5	-4.533(S)	- 5.116(SI)	- .6330(D)	+ 12.61(TS)
Total As	0.53	1549.0	22.93(SI)	- 22.63(D)	- 251.1(pH)	
Soluble P	0.72	80.55	.4062(C)	- .2657(SO4)	+ .0025(EC)	
<u>Variable Codes</u>						
S	= sand (%)	MC	= moist consistence	pH	= pH (paste)	R = rock (%)
Si	= silt (%)	MV	= moist value	EC	= Electrical conductivity (mmhos/cm)	D = depth (in)
C	= clay (%)	MCH	= moist chroma	TS	= log total sulfur (ppm)	SO4 = log sulfate (ppm)

value and considering the number of samples (or more precisely the degrees of freedom) in the population the significance level of the equation can be determined. For the Silver Bow Creek data (where $n=46$), an R^2 value greater than .40 indicates a highly significant (probability > 0.95) correlation.

The purpose of this analysis for the Silver Bow Creek data was simply to discover if significant correlations might exist within the data that could be defined and classified using more sophisticated procedures. Some of the variables required further transformation or exclusion in subsequent analyses so that these equations have no quantitative use, however they qualitatively indicate that the field variables selected (pH, EC, texture) are highly correlated with the degree of contamination (metal levels).

3.5 Screening Variables

Some parameters within a multivariate data set may not exhibit sufficient variability to be useful in distinguishing between observations. In order to clarify further analysis such parameters can be identified and excluded from further consideration using the principal components procedure.

The correlation of a data set can be described by, what are termed, its principal components. The principal components of a data set are independent functions of the original parameters with coefficients equal to the eigenvectors of the correlation matrix.

The first principal component is the linear combination of parameters that attains maximum discrimination between observations. A set of principal components will be ordered such that the second principal component will be the linear combination of parameters attaining maximum discrimination of observations uncorrelated with the first principal component. Subsequent principal components will attain the maximum discrimination from residual correlations independent of preceding principal components.

Variables which have small coefficients in the first few principal components contribute relatively little to sample variance and can thus be eliminated in further multivariate analyses.

The raw Silver Bow Creek data set was loaded in the Montana State University Vax 11-780 computer system. The principal component analysis was run using the PRINCOMP procedure which is part of SAS system software developed by the SAS Institute Inc. of Cary, North Carolina. The data set originally contained 46 observations with 80 parameters. Since the objective of the multivariate analysis was to group tailings using simple observations, 12 parameters which are listed in Table 3.3 were

identified as readily determined field observations or simple lab analyses.

Table 3.3 Parameters Used in Principal Components Analysis

% Sand	Moist Value	pH
% Silt	Moist Chroma	EC
% Clay	Moist Consistence	Total Sulfur
% Rock	Depth of Sample	Sulfate (extractable)

The first three principal components of this reduced data set accounted for two-thirds of the total variance. Of the 12 parameters, depth of sample and moist consistence proved to contribute relatively little to the first three principal components. Output summary tables are given in Appendix C.

Some parameters required additional transformation or omission for subsequent analyses. Rock and sand fractions were combined to create a new normalized parameter - ROCKSAND. The clay variable was omitted to avoid singularity problems with rock, sand, and silt. Moist value, moist chroma, and moist consistence were eliminated since those values were derived from a non-quantitative scale. Despite strong contributions, total sulfur and sulfate parameters were eliminated for the following steps since these values would have to be obtained from laboratory analyses (these variables could be used later if they were needed).

3.6 Classification

After the key field variables were identified in the screening stage, the data could then be classified (or grouped) using the heuristic techniques of the cluster procedure. Cluster analysis will assign observations to clusters (or classes) suggested by the data. Observations within a given class tend to be similar to each other in some sense and dissimilar to observations found in other classes.

Classes may be hierarchical, meaning that they may be entirely contained within another class, but no partial overlap of classes is allowed (some clustering methods will allow overlapping classes). Hierarchical clustering uses agglomerative methods to form classes. Each observation begins in a class by itself. The two closest (or most similar) classes are then merged to form a new class that replaces the two previous classes. The procedure iterates

until only one class remains containing all observations. A tree diagram can be derived that illustrates the history of each clustering iteration.

The reduced parameter set (pH, EC, rocksand, and silt) from the Silver Bow Creek data set was classified using a multivariate cluster analysis. The CLUSTER procedure in the SAS system software was used for this step. Classes were then assigned to each observation in preparation for the final task in each analysis.

The representative tree diagram illustrating the class boundaries is shown in Figure 3.3. The observations are shown on the horizontal scale and the statistical distance between cluster centroids is shown on the vertical scale. The characteristics of each class are discussed in Section 4.

3.7 Data Discrimination

The cluster method assigned existing tailings samples to groups (or classes) but did not define criteria for the assignments or provide a means to predict class membership for subsequent samples. Canonical discriminant analysis (or discriminant function analysis) is used to derive a decision scheme for classifying new cases. Discriminant analysis also provides a test for the adequacy of classification (can the groups be significantly discriminated or how reliable was the classification procedure for the original population?).

The analytical model is similar to principal components analysis in that it summarizes the "between class" variation the way that principal components summarize the "total" variation. As in the principal components procedure, canonical variables are derived and represent a linear combination of parameters exhibiting the highest multiple correlation within classes. Canonical variables are sorted in descending order of correlation. Class separation can be viewed in a plot of canonical variables. If the data can be discriminated, the classification can be thought of as meaningful.

The CANDISC procedure in the SAS system software was utilized in this step and plots were created to aid in visual interpretation of waste classes. The plots are shown in Figures 3.4 - 3.5. Classes 3.4 and 3.5 identified by clustering (Figure 3.3) could not be statistically separated from other classes by the CANDISC procedure. Hence, they were all grouped together and designated class 3 in the CANDISC routine. Predictive equations that were derived from this analysis are presented in Section 4.1 with a discussion. A detailed summary of the Canonical Discriminant Analysis is presented in Appendix E.

TREE DIAGRAM DERIVED FROM CLUSTER PROCEDURE
USING MULTITECH, 1986 DATA SET

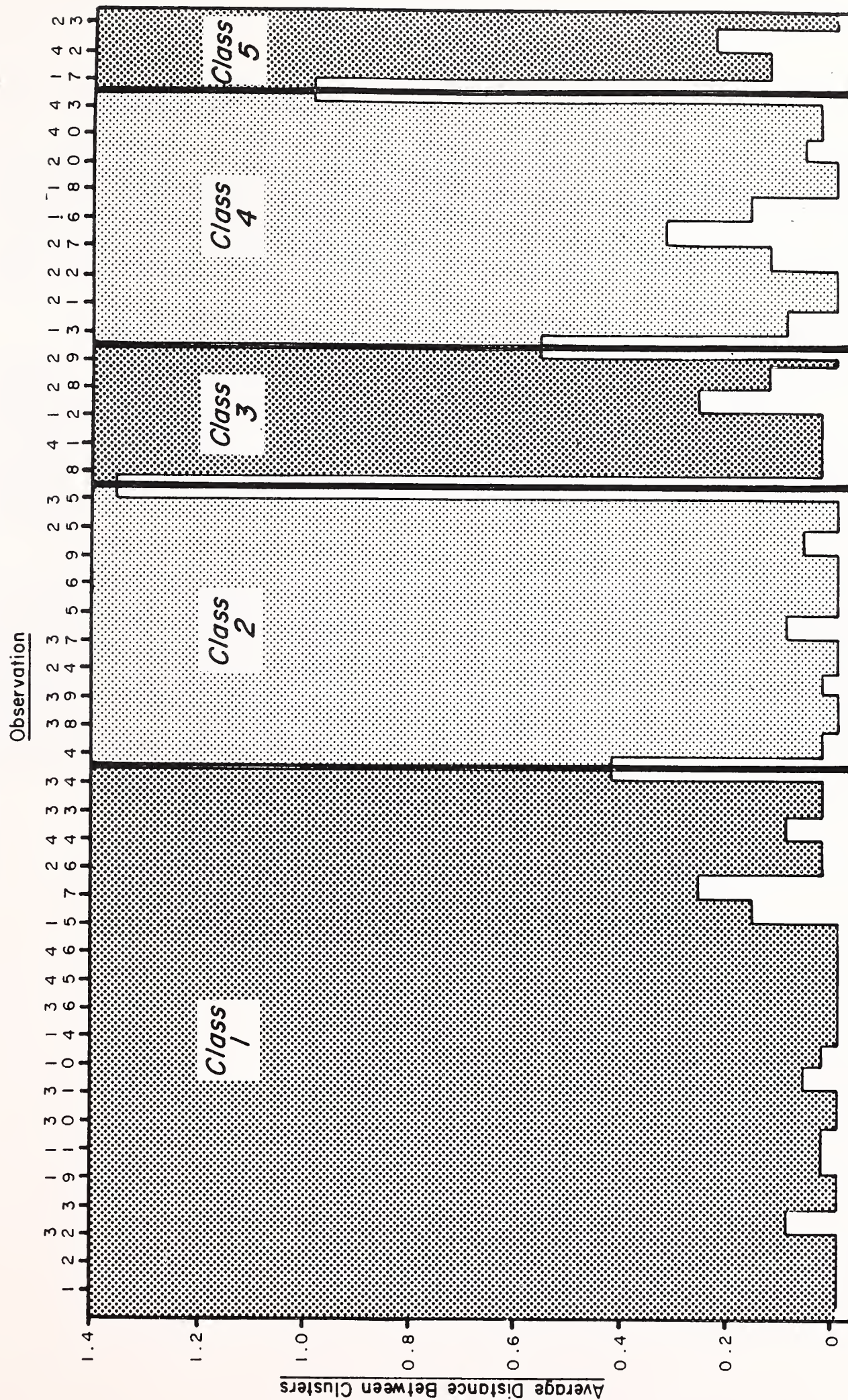


Figure 3.3 The diagram developed from the cluster analysis of 46 phase 1 RI tailings samples.

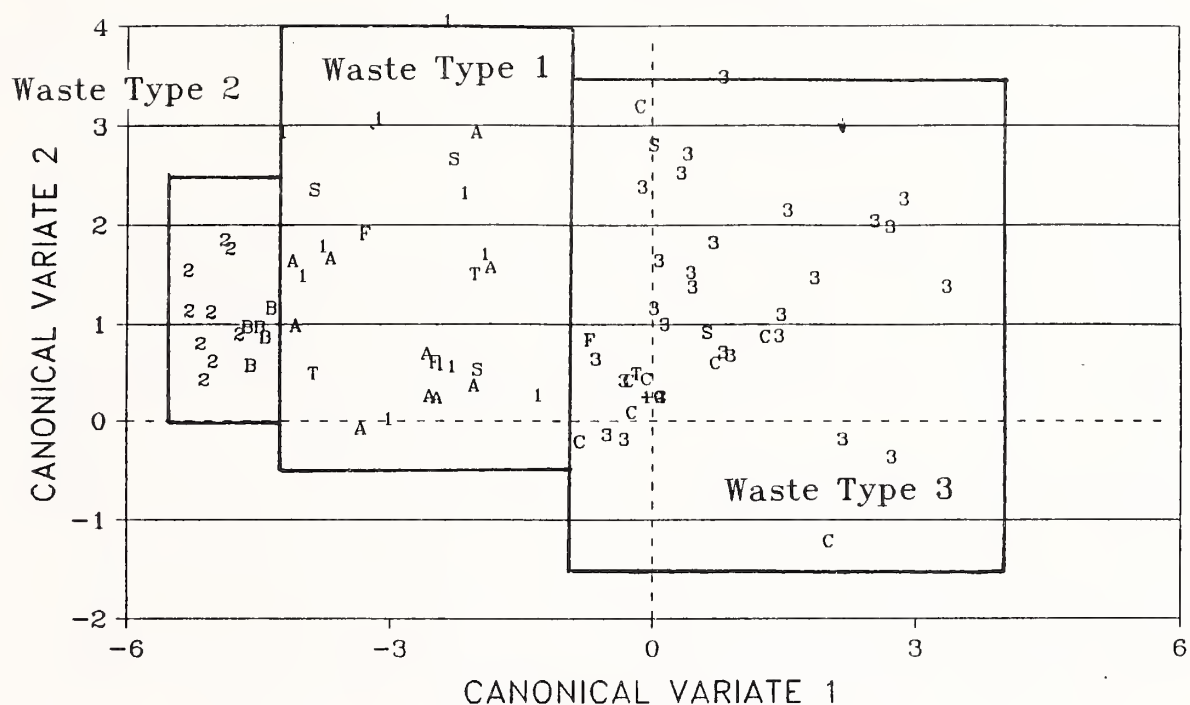
3.8 Numerical Model Testing

In order to test the validity of the numerical ranking model developed through the CANDISC procedure, a second group of data from an independent set of samples collected along the same reach of Silver Bow Creek was classified. The calculated canonical variates for the new samples should show similar grouping as for the initial data set. Secondly, the groups formed should be chemically and physically similar.

Figures 3.4 and 3.5 present the combined plots from the phase 1 data set (symbols 1,2,& 3) and from the new data set (symbols A,B,C,T,S,& F) which consisted of 35 bulk samples. Samples from both data sets when combined provided nearly coincident groups of points indicating that the numerical classification developed is able to identify distinct kinds of waste. Note that tailings types T, S, and F were not numerically classified by this model but their canonical scores are shown for comparison.

The characteristics of each waste type is summarized in Table 3.4. In both data sets, the same general characteristics of each waste type are apparent. Type 1 waste materials are high in sand and coarse fragments but also have a significant quantity of silt. Both pH and EC values are intermediate to the other groups. Type 2 wastes are extremely coarse-textured, have the lowest observed pH and EC levels. Type 3 wastes are higher in silt content than other groups and generally have somewhat higher pH and EC levels.

SILVER BOW CREEK / STARS WASTE RANKING



LEGEND

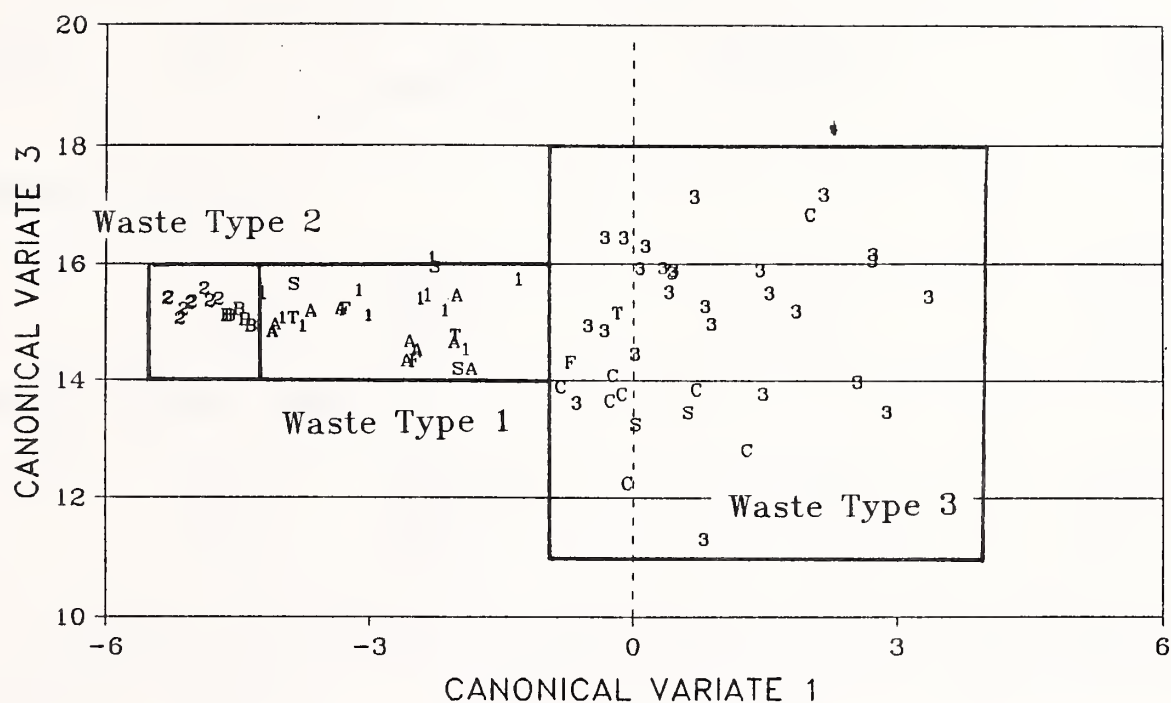
RI SAMPLES		BULK SAMPLES	
1	- Type 1	A	- Type 1
2	- Type 2	B	- Type 2
3	- Type 3	C	- Type 3
		T	- Tailings
		S	- Buried soil
		F	- Flooded (Ag) soil
pH	- Paste pH	RS	- Rock + sand (%)
EC	- Paste Electrical Cond. (micromhos)	Si	- Silt (%)

$$CAN1 = (.0113 * pH) + (.0000323 * EC) - (.0542 * RS) + (.0498 * Si)$$

$$CAN2 = (.817 * pH) + (.000125 * EC) - (.0232 * RS) - (.0623 * Si)$$

Figure 3.4 Plot of canonical variates 1 and 2 showing distribution of Silver Bow Creek phase 1 RI data and STARS phase 2 bulk samples into three distinct groups.

SILVER BOW CREEK / STARS WASTE RANKING



LEGEND

RI SAMPLES	1 - Type 1	BULK SAMPLES	A - Type 1
	2 - Type 2		B - Type 2
	3 - Type 3		C - Type 3
pH - Paste pH	RS - Rock + sand (%)		T - Tailings
EC - Paste Electrical Cond. (micromhos)	Si - Silt (%)		S - Buried soil
			F - Flooded (Ag) soil

$$\text{CAN1} = (.0113 * \text{pH}) + (.0000323 * \text{EC}) - (.0542 * \text{RS}) + (.0498 * \text{Si})$$

$$\text{CAN3} = (.0453 * \text{pH}) + (.0000491 * \text{EC}) + (.149 * \text{RS}) + (.173 * \text{Si})$$

Figure 3.5 Plot of canonical variates 1 and 3 showing distribution of Silver Bow Creek phase 1 RI data and STARS phase 2 bulk samples into three distinct groups.

Table 3.4 average levels of field variables for different waste types.

CLASS	pH	EC (μ MHOS/CM)	ROCKSAND (%)	SILT (%)
<u>Phase 1 RI data</u>				
1	4.7 A*	4600 AB	73.6 A	19.8 A
2	3.5 B	2400 A	96.6 B	2.0 B
3	5.1 A	7600 B	35.0 C	52.4 C
<u>Phase 2 "bulk" Samples</u>				
1	3.9 A	3480 AB	72.8 A	18.5 A
2	3.6 B	1300 A	90.0 B	6.0 B
3	4.0 A	4550 B	37.7 C	43.2 C

* - numbers followed by the same letter are not significantly different ($p < .05$).

Average texture for each waste type from the two data sets were nearly identical. There appeared to be variability in pH and EC in the phase 1 RI data set, however, especially with class 3 wastes having substantially higher pH (5.1) and EC (7600) than was measured in the bulk samples (pH = 4.0, EC = 4600). This apparent difference in chemistry may represent real differences caused by climate or seasonal variation. The chemical differences between data sets may also have been caused by the deeper average depth at which the bulk samples were collected. Despite these minor shifts in chemistry, however, samples from the two data sets appear to be uniformly classified using the canonical functions.

4.0 SILVER BOW CREEK ANALYSIS

The procedures outlined in section 3.0 were used to analyze data on streambank tailings collected during the RI/FS of Silver Bow Creek. A summary of the results and application of this analysis is presented and discussed in this section. Detailed statistical results of the analyses are provided in the Appendices.

4.1 Waste Ranking Summary

Most chemical parameters including sulfur forms, soluble metals, extractable metals, and total metals followed a log-normal distribution. They were transformed to approximate a normal distribution by taking the base 10 log of the value. All chemical parameters (except pH and EC) are expressed as the log of the concentration in micrograms per gram of soil.

Field-measured variables (like pH, EC, and texture) were found to correlate highly with metal concentrations. As a result, field variables were used to rank waste materials into differing groups. The different waste groups have differing requirements for remediation.

A principle components analysis was used to select those field variables that were most useful in classifying tailings samples into groups. The first three principle components accounted for two-thirds of the between sample variability. Hence, variables were chosen that were significantly weighted in the first three principle components.

The cluster procedure grouped all tailings samples into the five classes shown on the tree diagram in Figure 3.3. Over half of the observations were accounted for in classes one and two. Classes four and five were merged with class three due to their relative proximity (or similarity) to class three.

Using the groups defined by the cluster procedure, a canonical discriminant analysis was used to develop a simple numerical expression for classifying new samples into the defined groups. Statistical analysis of the canonical analysis indicated that the separation of groups provided by the numerical ranking was highly significant. An independent data set was ranked using the numerical model and similar waste groups were obtained (Figure 3.4 and 3.5). Mean levels of field variables within each defined class were similar for each data set thus confirming that the ranking system reliably separates waste differences.

The tailings classes can be distinguished using 4 field variables - pH, EC, coarse fraction (%), and silt (%). Class one tailings represent a group having intermediate values for all

four field variables - somewhat acidic pH, moderate EC, moderate to moderately high coarse fraction and a significant silt fraction. Class two tailings are very coarse-textured with minimal silt content and have much lower pH and EC values. Class three tailings are the least acidic, have the highest EC values, and have a high silt content. Generalized field identification criteria are given in Table 4.1.

Table 4.1 Field classification criteria for Silver Bow Creek tailings.

	<u>pH</u>	<u>EC</u>	<u>Coarse Fraction (%)</u> *	<u>Silt Fraction (%)</u> *
CLASS I	3.0-4.0	2000-5000	50-85	10-30
CLASS II	3.5-4.5	500-2500	>85	<10
CLASS III	3.5-5.5	4000-12000	<50	>30

* Percentages are based on total sample volume

Values listed in Table 4.1 represent rough field guidelines for the classification of tailings. More precise classifications should be based on the equations derived from the discriminant analysis procedure which are presented in Table 4.3.

Tailings types classified from the 35 bulk samples differed in key field parameters (Table 4.1) and also varied in levels of metals and sulfur (Table 4.2). Type 3 tailings were in general highest, and type 2 tailings lowest, in total and soluble metals. Type 1 tailings appeared to be highest in total sulfur with type 2 tailings were lowest in total sulfur.

Table 4.2 Comparison of metal and sulfur levels in three tailings types.

Class	Total S	Pyritic S	----- Cu	log Total Zn (mg/kg)	----- As	----- Pb	----- log Soluble Cu (mg/l)	----- Zn	----- As	----- Pb
1	1.6AB*	0.8A	3.1A	3.1A	2.4A	2.9A	2.1A	2.3A	-1.4AB	-1.5A
2	0.3A	0.1A	2.4B	3.1A	1.9A	2.4A	0.8B	1.3B	-1.9A	-2.2A
3	1.4 B	0.3A	3.4A	3.6A	3.1B	3.2B	2.7C	2.7C	-0.9 b	-1.5A

* - numbers followed by the same letter are not significantly different at (p<.05).

4.2 Use of Waste Ranking System

While development of the waste ranking system for Silver Bow Creek Streambank tailings involved use of numerous complex multivariate statistical techniques, use of the ranking system is straight forward (Table 4.3). In order to rank a new waste sample the pH, and EC (in umhos/cm in a saturated extract) must be measured. Next, the rock, sand, and silt contents must be measured or estimated. While the hydrometer and sieve tests can be used to measure soil texture fractions, a good estimate of texture (Appendix F) will also suffice.

Next, canonical variates must be calculated to determine the class membership. Use of canonical variate 1 is adequate for ranking a sample, but use of variate 2 and 3 provide useful confirmation of class membership. Compare the value of the canonical variates to the ranges listed in Table 4.2 to determine class membership. Waste samples that do not fit the class boundaries should be denoted as "outliers". If a substantial number of outliers are identified in future investigations, further refinement of analytical techniques or development of the ranking model may be necessary.

4.3 Conclusions

The waste ranking model can successfully discriminate between different kinds of waste found along Silver Bow Creek. The types of streambank tailings classified with this model vary in their basic chemical and physical properties. As a result, different remedial methods will need to be developed to mitigate impacts from each type of waste. The objective of the STARS project being conducted as part of the Silver Bow Creek RI/FS is to develop cost-effective remedial measures for streambank tailings.

Other factors are expected to affect the selection of appropriate remedial measures in addition to tailings type. These factors include the depth to groundwater and tailings thickness. In support of the RI/FS, maps should be prepared which indicate the distribution of various waste types, the depth to groundwater, and the thickness of tailings found in various areas within the Streamside Tailings operable unit. A Feasibility Study report can be prepared based on the results of the STARS investigation and on the outcome of mapping efforts.

Table 4.3 Waste ranking model for the Silver Bow Creek streambank tailings operable unit.

CANONICAL VARIATE	CANONICAL MODEL	-----CLASS LIMITS-----		
		CLASS 1	CLASS 2	CLASS 3
1	$(0.0113 \times \text{pH}) + (.0000323 \times \text{EC}) -$ $(.0542 \times \text{RS}) + (.0498 \times \text{Si})$	-4.3 to -1	-5.5 to -4.3	-1 to 4
2	$(.817 \times \text{pH}) + (.000125 \times \text{EC}) -$ $(.0232 \times \text{RS}) - (.0623 \times \text{Si})$	-0.5 to 4	0 to 2.5	-1.5 to 3.5
3	$(.0453 \times \text{pH}) + (.0000491 \times \text{EC}) +$ $(.149 \times \text{RS}) + (.173 \times \text{Si})$	14 to 16	14 to 16	11 to 18

EC = electrical conductivity (saturated paste extract umhos/cm)

RS = rock and sand (%) based on whole sample weight

Si = silt (%) based on whole sample weight

APPENDIX A

DATA SUMMARY TABLES
for Silver Bow Creek, Phase 1 RI Data
and Phase 2 (STARS) Bulk Samples

Table 1-1. Data used in the Silver Bow Creek statistical analysis.

SILVER BOW CREEK PHASE 1 RI / TAILINGS DATA TEXTURE, pH, EC								
SAMPLE	SITE	DEPTH (in)	pH	EC (mmhos/ cm)	SAND (%)	SILT (%)	CLAY (%)	ROCK (%)
1	1	7.5	3.7	3630.0	67.9	26.0	6.1	7.2
2	1	17.0	4.2	3640.0	92.0	4.2	3.8	47.4
3	1	22.5	6.0	2990.0	88.3	8.7	3.0	3.1
6	2	2.0	3.4	352.0	95.3	0.7	4.0	37.6
7	2	9.0	3.2	906.0	73.6	20.4	6.0	4.6
8	2	20.5	2.9	1020.0	95.2	1.8	3.0	51.8
9	2	35.0	4.4	2010.0	45.2	42.8	12.0	2.7
11	3	4.0	3.1	7210.0	17.7	42.3	40.0	10.3
12	3	15.0	3.8	984.0	94.9	2.8	2.3	39.0
13	3	28.5	5.0	3150.0	31.2	54.9	13.9	5.2
14	3	40.5	7.0	2880.0	9.1	67.3	23.6	6.3
17	4	2.5	2.6	7030.0	90.9	4.3	4.8	60.6
18	4	6.5	2.4	12300.0	72.2	24.3	3.5	0.6
19	4	16.0	2.8	3270.0	94.7	2.4	2.9	56.7
20	4	28.0	4.4	3330.0	94.2	4.2	1.6	38.9
21	5	5.0	3.6	11500.0	43.4	39.6	17.0	0.4
22	5	17.0	3.7	17000.0	46.6	43.7	9.7	3.5
23	5	31.5	6.0	10600.0	42.8	48.2	9.0	3.1
24	5	45.5	7.2	3020.0	9.1	64.8	26.1	0.5
26	6	2.0	3.7	10700.0	62.8	23.3	13.9	1.9
27	6	8.5	3.6	12900.0	26.0	50.1	23.9	1.2
28	6	23.5	3.8	12900.0	48.2	45.8	6.0	<0.1
29	6	23.5	3.5	15800.0	31.2	57.2	11.6	4.3
33	7	6.0	4.3	627.0	98.6	0.0	1.6	49.6
34	7	15.5	3.7	1310.0	98.8	0.0	1.4	44.3
37	8	7.0	3.6	5380.0	51.2	46.2	12.6	1.4
38	8	23.0	5.3	13600.0	46.7	47.4	5.9	9.3
39	8	37.5	5.6	8500.0	73.8	19.5	6.7	22.5
40	8	52.0	6.1	9330.0	21.6	64.0	14.4	12.8
41	9	7.5	4.0	2760.0	58.5	36.3	5.2	2.1
42	9	18.5	6.2	2780.0	38.8	53.4	7.8	5.0
44	9	37.0	6.3	3660.0	23.7	62.3	7.4	2.3
48	10	5.0	7.2	4570.0	37.4	51.8	10.8	6.8
49	10	17.5	7.7	4830.0	69.1	24.1	6.8	1.6
52	11	12.5	3.8	1390.0	46.9	42.2	10.9	3.6
53	11	44.5	5.9	3240.0	65.4	26.7	7.9	3.4
67	18	3.5	4.4	575.0	45.7	35.6	18.7	0.4
70	20	3.0	5.1	216.0	78.7	14.1	7.2	16.8
71	21	3.0	4.7	224.0	83.6	11.3	5.1	6.2
72	22	3.0	4.7	10300.0	43.0	48.3	8.7	0.2
73	23	2.5	7.7	7400.0	33.3	52.9	13.8	5.8

Table 1-1. (Continued).

SAMPLE	SITE	DEPTH (in)	pH	EC (nmhos/ cm)	SAND (%)	SILT (%)	CLAY (%)	ROCK (%)
82	25	3.5	4.3	17900.0	13.2	69.3	17.5	0.1
83	25	12.0	3.6	10100.0	20.5	69.6	9.9	0.0
88	28	4.5	4.8	5240.0	28.1	70.1	1.8	0.4
89	28	15.0	7.0	3270.0	42.5	57.5	0.0	0.9
90	28	25.0	7.6	3250.0	18.7	71.4	9.9	0.3

Table 1-1 (continued)

SILVER BOW CREEK
PHASE IRI / TAILINGS DATA
COLOR, CONSISTENCE, ARSENIC, & PHOSPHORUS

SAMPLE	MOIST VALUE	MOIST CHROMA	MOIST CONSISTENCE	AVAILABLE ARSENIC (ppm)	SOLUBLE ARSENIC (ppm)	SOLUBLE PHOSPHORUS (ppm)
1	5	8	2	610.00	1.860	3.240
2	5	8	5	488.00	<0.980	<1.270
3	3	1	2	153.00	9.240	4.770
6	5	6	2	376.00	1.070	<1.270
7	3	4	2	430.00	1.020	5.610
8	5	6	4	392.00	2.540	<1.230
9	3	2	2	59.20	1.000	50.800
11	5	8	3	2950.00	261.000	18.600
12	5	8	5	497.00	12.300	4.060
13	4	3	2	52.60	<0.965	<1.250
14	4	1	3	55.20	0.000	0.000
17	6	6	1	109.00	<0.980	2.980
18	5	1	3	88.60	4.600	12.800
19	5	8	1	297.00	<0.965	<1.250
20	3	2	1	255.00	<0.980	<1.270
21	6	4	3	1800.00	73.600	13.900
22	4	4	3	1910.00	7.630	7.840
23	3	1	3	350.00	<1.440	8.300
24	4	2	3	56.20	0.000	0.000
26	4	3	2	1020.00	35.500	13.600
27	5	2	1	2240.00	45.600	9.690
28	4	6	3	1830.00	8.300	6.000
29	3	3	3	1510.00	11.500	10.800
33	4	6	1	418.00	<1.440	<0.973
37	7	2	2	1860.00	3.380	3.420
38	3	3	3	754.00	<1.680	15.500
39	4	3	2	422.00	2.110	7.540
40	4	2	2	88.60	<1.630	10.000
41	5	2	2	1260.00	<1.680	<1.900
42	4	2	2	922.00	<1.680	<1.900
44	4	2	2	155.00	<1.660	2.330
48	5	4	3	1940.00	0.000	0.000
49	4	2	3	39.70	0.000	0.000
52	6	8	2	592.00	5.990	5.580
53	3	2	2	564.00	16.600	7.140
67	4	6	2	1210.00	2.680	5.120
70	3	3	1	176.00	38.900	70.400
71	4	3	1	522.00	36.100	72.800
72	4	6	1	290.00	3.600	6.190
73	4	6	3	424.00	0.000	0.000

Table 1-1 (continued)

SAMPLE	MOIST VALUE	MOIST CHROMA	MOIST CONSISTENCE	AVAILABLE ARSENIC (ppm)	SOLUBLE ARSENIC (ppm)	SOLUBLE PHOSPHORUS (ppm)
82	4	5	3	2520.00	28.400	13.400
83	4	4	3	2680.00	10.200	5.920
88	4	5	2	2130.00	6.990	1.630
89	3	4	3	88.00	2.900	0.574
90	3	3	3	182.00	0.000	0.000

Table 1-1. (continued)

SILVER BOW CREEK
 PHASE 1 RI / TAILINGS DATA
 SULFUR AND SULFATE DATA AND
 SATURATION EXTRACTABLE METALS DATA

SAMPLE	TOTAL SULFUR (log ppm)	PYRITIC SULFUR (log ppm)	EXTRACTABLE SULFATE (log ppm)	COPPER (log ppm)	CADMIUM (log ppm)	MANGANESE (log ppm)	ZINC (log ppm)
1	3.8	3.2	3.6	2.241	-0.370	0.436	1.49
2	3.6	3.6	3.4	0.566	-1.553	-0.305	0.81
3	3.7	3.6	3.0	0.467	-1.678	-1.108	0.58
6	3.1	3.5	2.9	0.650	-1.921	0.201	0.36
7	3.4	3.1	3.0	1.459	-0.914	0.577	1.18
8	3.1	3.3	3.0	1.121	-0.971	0.267	1.42
9	2.8	3.0	2.4	1.134	-0.100	0.574	1.57
11	2.9	2.7	3.8	2.916	0.176	2.504	2.70
12	3.3	2.7	2.8	1.274	-1.409	0.919	1.09
13	3.2	3.4	3.5	2.173	-0.381	1.759	1.71
14	3.2	3.4	3.2	-0.658	-2.046	1.899	0.77
17	3.7	3.5	3.6	1.061	-0.764	1.348	0.77
18	4.7	4.8	3.7	1.387	-0.092	1.446	1.23
19	3.6	3.5	3.5	0.975	-1.237	0.751	0.85
20	3.6	3.6	3.4	2.412	0.093	0.719	1.56
21	3.9	3.0	3.9	2.937	0.401	2.926	2.89
22	4.1	3.2	4.2	3.193	0.634	3.258	3.18
23	4.0	3.4	4.3	1.507	0.723	3.238	2.99
24	3.1	3.5	3.7	-0.678	-1.921	-0.514	0.77
26	4.0	3.1	3.8	2.882	0.241	2.795	2.77
27	4.0	3.1	4.1	3.193	0.467	3.167	3.09
28	4.0	3.0	4.1	3.140	0.496	3.255	3.16
29	4.1	3.1	4.2	3.292	0.625	3.334	3.24
33	3.4	3.4	2.8	1.037	-1.585	0.571	0.83
34	3.8	3.7	2.7	1.517	-0.971	1.029	1.48
37	3.8	3.1	3.6	1.427	-0.072	2.597	2.34
38	4.2	3.4	4.3	2.111	0.757	3.589	3.03
39	3.7	3.0	4.0	1.641	0.375	2.944	2.52
40	3.8	3.1	4.1	0.854	0.713	3.164	2.81
41	3.7	3.0	3.4	1.699	-0.609	1.959	1.90
42	3.9	3.8	3.3	0.299	-0.636	1.691	1.59
44	3.3	3.2	3.4	-0.372	-0.346	2.276	1.75
48	3.5	3.2	3.2	-0.393	-1.569	-1.201	-0.59
49	3.1	2.8	2.9	-0.754	-1.481	-1.469	-1.22
52	3.8	2.8	3.5	2.262	0.286	2.623	2.91
53	3.5	3.5	3.7	0.236	-0.431	1.605	1.83
67	3.6	3.2	2.7	0.491	-1.222	0.591	0.91
70	2.2	3.2	0.9	-1.569	-2.155	-0.815	-1.40
71	4.0	2.9	0.9	-1.046	-2.155	-0.580	-0.57
72	4.0	3.0	4.2	2.705	0.307	2.551	2.77
73	3.9	3.5	4.0	0.274	-1.509	-0.903	-0.57

Table 1-1. (continued).

SAMPLE	TOTAL SULFUR (log ppm)	PYRITIC SULFUR (log ppm)	EXTRACTABLE SULFATE (log ppm)	COPPER (log ppm)	CADMIUM (log ppm)	MANGANESE (log ppm)	ZINC (log ppm)
82	4.0	2.9	4.1	2.638	0.494	3.230	2.94
83	3.9	3.0	4.0	2.994	0.953	3.453	3.22
88	3.9	3.3	3.0	1.722	-0.321	2.281	2.12
89	3.7	3.7	3.6	-1.018	-1.301	1.100	0.67
90	3.2	3.3	3.6	-0.947	-1.699	-1.495	-0.89

Table 1-1. (continued)

SILVER BOW CREEK
PHASE 1 RI / TAILINGS DATA
AMMONIUM ACETATE EXTRACTABLE
METALS DATA

SAMPLE	COPPER (log ppm)	CADMIUM (log ppm)	MANGANESE (log ppm)	ZINC (log ppm)	IRON (log ppm)	LEAD (log ppm)
1	2.84	-0.08	0.74	1.83	1.85	-0.24
2	2.06	-1.10	-0.10	1.30	0.93	1.20
3	3.16	-0.59	-0.40	1.84	-0.15	0.82
6	1.83	-1.40	1.02	1.23	1.12	0.81
7	2.27	-0.28	1.21	1.87	1.72	-0.34
8	1.79	-0.34	0.91	2.08	1.33	-0.21
9	2.75	1.24	1.65	2.78	0.40	1.64
11	3.09	0.25	2.67	2.84	1.74	-0.38
12	2.22	-0.55	1.84	1.98	1.40	-0.74
13	1.57	0.43	2.59	2.58	0.97	0.94
14	0.00	0.08	3.03	2.84	-0.52	1.44
17	1.15	-0.89	1.41	1.01	2.62	-0.18
18	1.04	-0.52	1.33	1.04	3.08	0.04
19	1.08	-1.10	1.00	0.99	2.22	-0.59
20	2.85	0.17	0.85	1.66	0.71	0.68
21	3.23	0.64	3.12	3.13	2.17	1.10
22	3.43	0.88	3.40	3.36	2.28	-0.08
23	3.80	1.43	3.59	3.61	0.92	3.36
24	0.78	0.23	1.63	3.11	-0.52	0.76
26	3.11	0.45	2.94	2.93	1.89	-0.09
27	1.39	0.66	3.27	3.22	2.23	-0.18
28	3.39	0.72	3.40	3.33	1.90	-0.30
29	3.50	0.80	3.49	3.40	2.38	-0.30
33	2.16	-0.74	1.28	1.61	0.56	0.99
34	1.81	-0.72	1.21	1.72	1.34	0.53
37	2.94	0.35	2.92	2.70	1.91	-0.06
38	4.03	1.24	3.72	3.36	1.63	3.45
39	3.37	0.78	3.22	2.97	1.08	1.95
40	3.18	1.45	3.55	3.50	0.15	2.79
41	2.61	0.06	2.52	2.49	1.74	1.10
42	3.52	0.55	2.36	2.84	-0.22	3.35
44	2.73	0.94	3.13	3.13	1.00	3.54
48	2.88	0.62	1.36	2.78	0.64	0.65
49	0.60	-0.34	0.84	0.40	-0.52	-1.22
52	2.47	0.39	2.65	2.93	1.63	-0.96
53	2.89	0.68	2.34	2.78	0.15	2.40
67	2.50	0.32	1.91	2.29	1.24	-0.32
70	1.23	-0.22	1.41	1.03	0.23	0.32
71	1.63	-0.34	1.12	1.25	0.75	0.58
72	3.39	0.66	2.81	3.07	0.63	-0.64
73	2.11	0.61	1.54	2.29	0.23	0.91

Table 1-1. (continued)

SAMPLE	COPPER (log ppm)	CADMIUM (log ppm)	MANGANESE (log ppm)	ZINC (log ppm)	IRON (log ppm)	LEAD (log ppm)
82	3.09	0.93	3.52	3.27	1.83	-2.00
83	3.04	0.57	3.33	3.06	1.52	1.87
88	3.03	0.26	2.64	2.54	1.34	2.14
89	3.34	0.75	2.56	2.71	0.92	3.47
90	1.85	0.11	1.67	2.26	0.36	1.68

Table 1-1. (continued)

SILVER BOW CREEK
PHASE 1 RI / TAILINGS DATA
TOTAL METALS DATA

SAMPLE	COPPER (log ppm)	CADMIUM (log ppm)	MANGANESE (log ppm)	ZINC (log ppm)	IRON (log ppm)	LEAD (log ppm)
1	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00
14	3.12	1.07	3.36	3.62	4.47	2.57
17	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00
26	3.38	1.14	3.43	3.70	4.46	3.18
27	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00
39	3.63	1.09	3.44	3.43	4.24	2.84
40	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00
52	3.09	1.30	3.18	3.88	1.42	3.11
53	3.71	1.23	3.98	3.91	1.38	3.51
67	3.28	1.20	3.18	3.58	4.55	3.19
70	2.58	0.40	2.68	2.30	4.18	1.96
71	3.64	0.87	2.93	3.37	4.26	2.50
72	3.69	1.15	2.72	3.31	4.25	2.05
73	3.36	1.08	3.23	3.39	4.28	2.55

Table1-1. (continued)

SAMPLE	COPPER (log ppm)	CADMIUM (log ppm)	MANGANESE (log ppm)	ZINC (log ppm)	IRON (log ppm)	LEAD (log ppm)
82	3.47	1.42	3.55	3.86	4.47	3.32
83	3.52	1.34	3.42	3.84	4.44	3.45
88	3.54	1.33	3.39	3.92	4.54	3.68
89	3.78	1.33	4.17	4.20	4.53	3.87
90	2.78	0.95	3.59	3.35	4.45	3.14

Table . Total metal levels of the 35 bulk samples from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
TOTAL METALS : HNO3/H2O2 Extract

Site Sample Number	Type	ITR Number	Total Al (mg/ kg)	Total As (mg/ kg)	Total Cd (mg/ kg)	Total Cr (mg/ kg)	Total Cu (mg/ kg)	Total Fe (mg/ kg)	Total Mn (mg/ kg)	Total Pb (mg/ kg)	Total Zn (mg/ kg)	Total Hg (mg/ kg)
1	559-2-1	N	3538H-77	3790.00 *	1003.00 *	13.20 UN*J	2.80 NJ	2150.00	1540.00	1490.00	3940.00 EJ	15.00 J
2	559-3-1	N	3538H-76	350.00 *	1745.00 *	108.00 N*J	1.60 UNJ	11200.00	287.00	1960.00	22000.00 EJ	4.40 J
3	559-4-1	N	3538H-75	227.00 *	354.00 *	26.90 N*J	1.60 UNJ	208.00	46.50	908.00	5580.00 EJ	1.40 J
4	556-3-1	N	3538H-60	6380.00 *	146.00 *	4.50 N*J	10.50 NJ	2150.00	528.00	398.00	2970.00 EJ	1.20 J
5	556-1-1	N	3538H-69	2400.00 *	975.00 *	32.20 N*J	1.60 UNJ	8620.00	7510.00	3100.00	7490.00 EJ	39.00 J
6	556-1-2	N	3538H-70	7200.00 *J	212.00 *J	15.70 N*J	2.60 NJ	6160.00	10300.00	4920.00	7860.00 EJ	61.00 J
7	556-2-1	N	3538H-66	3550.00 *	83.60 *	13.70 N*J	39.80 NJ	461.00	902.00	341.00	3840.00 EJ	2.20 J
8	553-1-1	N	3538H-50	2980.00 *	491.00 *	8.40	14.30	456.00 EJ	3680.00	1160.00	2480.00 EJ	36.00
9	553-1-2	N	3538H-59	4160.00 *	928.00 *	19.50 N*J	1.60 NJ	4040.00	13300.00	6477.00	10200.00 EJ	61.00 J
10	553-2-1	N	3538H-49	4000.00 *	51.20 *	3.60	11.00	811.00 EJ	98.20	312.00	814.00 EJ	0.85
11	551-1-1	N	3538H-62	3480.00 *	2544.00 *	38.60 N*J	2.00 NJ	1600.00	17.00	1672.00	2040.00 EJ	6.70 J
12	551-4-1	N	3538H-68	12700.00 *	38.90 *	15.00 N*J	10.50 NJ	3920.00	2020.00	264.00	3900.00 EJ	0.80 J
13	551-2-1	N	3538H-67	3020.00 *	285.00 *	2.80 N*J	14.70 NJ	374.00	1360.00	578.00	1380.00 EJ	2.80 J
14	551-3-1	N	3538H-54	6420.00	3140.00	36.40	34.80	5530.00 EJ	2130.00	3380.00	5290.00 EJ	24.00
15	547-1-1	N	3538H-82	3720.00	352.00	9.40	19.10	391.00 EJ	1320.00	504.00	2670.00 EJ	2.10
16	547-2-1	N	3538H-55	5490.00	1040.00	32.10	40.00	7430.00 EJ	44.10	2720.00	49.40 EJ	22.00
17	543-2-1	N	3538H-53	4550.00	204.00	4.70	20.90	260.00 EJ	599.00	273.00	1190.00 EJ	1.20
18	543-4-1	N	3538H-61	7080.00 *	1755.00 *	23.10 N*J	6.80 NJ	4070.00	968.00	1986.00	4460.00 EJ	22.00 J
19	541-3-1	N	3538H-78	4560.00 *	1530.00 *	22.60 N*J	4.30 NJ	2430.00	2430.00	1560.00	4120.00 EJ	7.90 J
20	541-4-1	N	3538H-65	3750.00 *	341.00 *	8.90 N*J	4.80 NJ	685.00	696.00 J	682.00	5020.00 EJ	2.90
21	537-1-1	N	3538H-79	7320.00	2560.00	37.00	31.20	3900.00 EJ	4010.00	2980.00	7430.00 EJ	25.00
22	537-2-1	N	3538H-52	9830.00	1050.00	21.90	31.70	4650.00 EJ	2910.00	2730.00	4150.00 EJ	26.00
23	529-1-1	N	3538H-56	17900.00	651.00	20.50	39.40	5080.00 EJ	2050.00	1840.00	5500.00 EJ	14.00
24	527-2-1	N	3538H-51	10000.00	414.00	16.60	20.20	1550.00 EJ	1280.00	1350.00	5580.00 EJ	7.90
25	517-1-1	N	3538H-71	3560.00 *	93.50 *	4.10 *NJ	8.40 NJ	390.00	108.00	442.00	937.00 EJ	1.00 J
26	513-1-1	N	3538H-81	7760.00	261.00	6.40	19.30	868.00 EJ	3500.00	635.00	1760.00 EJ	2.80
27	513-2-1	N	3538H-80	8830.00	235.00	12.60	22.00	1980.00 EJ	5440.00	2520.00	19.20 EJ	22.00
28	509-3-1	N	3538H-84	7040.00	203.00	14.40	19.30	779.00 EJ	4580.00	2180.00	2500.00 EJ	23.00
29	509-1-1	N	3538H-58	19700.00	83.90	5.70	24.30	329.00 EJ	970.00	125.00	476.00 EJ	0.10 U
30	505-2-1	N	3538H-57	6330.00 *	216.00 *	2.60	142.00	470.00 EJ	518.00	563.00	938.00 EJ	2.53
31	505-3-1	N	3538H-73	4420.00 *	114.00 *	4.10 N*J	5.50 NJ	1290.00	278.00	367.00	559.00 EJ	1.40
32	505-4-1	N	3538H-72	10800.00 *	19.30 *	8.80 N*J	12.90 NJ	1930.00	1640.00	82.60	2240.00 EJ	0.70 J
33	501-1-1	N	3538H-74	5420.00 *	209.00 *	1.80 N*J	7.60 NJ	871.00	1350.00	467.00	1110.00 EJ	2.00 J
34	488-1-1	N	3538H-83	6130.00	195.00	5.60	15.80	761.00 EJ	709.00	375.00	1440.00 EJ	2.00
35	486-1-1	N	3538H-63	7260.00 *	196.00 *	3.60 N*J	10.90 NJ	534.00	350.00	456.00	779.00 EJ	2.70 J

U - none detected, amount reported is the instrument detection limit (IDL)
 B - amount determined between the IDL and the contract required detection limit (CRDL)
 N - natural sample
 S - determined by method of standard addition (MSA)

N - spike recovery exceeds control limits
 E - estimation due to interferences
 + - correlation coefficient < 0.995
 * - duplicate exceeded control limits
 J - estimate
 R - unuseable data

Table . Total metals (suite 2) for the 35 bulk samples from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
TOTAL METALS II : HNO3/H2O2 Extract

Site Sample Number	Sample Name	ITR Number	Total Ca (mg/ kg)	Total Hg (mg/ kg)	Total Na (mg/ kg)	Total K (mg/ kg)
1	559-2-1	MHH509	1690.00	1560.00	2830.00 B	2050.00
2	559-3-1	MHH505	852.00 B	79.00 U	58.80 B	671.00 B
3	559-4-1	MHH506	315.00 B	78.20 U	98.30 B	425.00 B
4	556-3-1	MHH518	1620.00	3120.00	525.00 B	2710.00
5	556-1-1	MHH501	1640.00	854.00 B	558.00 B	979.00 B
6	556-1-2	MHH502	3360.00	3180.00	312.00 B	2180.00
7	556-2-1	MHH513	2220.00	1630.00	550.00 B	1850.00
8	553-1-1	MHH528	1030.00	1400.00	242.00 B	1310.00
9	553-1-2	MHH517	1070.00	1560.00	119.00 B	1620.00
10	553-2-1	MHH521	3750.00	1650.00	746.00	1670.00
11	551-1-1	MHH520	725.00 B	1680.00	512.00 B	2460.00
12	551-4-1	MHH508	11500.00	7160.00	140.00 B	4700.00
13	551-2-1	MHH512	836.00 B	1130.00	84.40 B	1100.00
14	551-3-1	MHH529	4880.00	2130.00	635.00 B	2640.00
15	547-1-1	MHH536	1680.00	1840.00	127.00	1410.00
16	547-2-1	MHH523	4680.00	3390.00	636.00 B	1780.00
17	543-2-1	MHH527	1020.00	2520.00	108.00 B	1820.00
18	543-4-1	MHH516	5430.00	2510.00	789.00 B	2650.00
19	541-3-1	MHH507	3300.00	2560.00	802.00 B	2590.00
20	541-4-1	MHH514	1120.00	1660.00	52.10 B	1590.00
21	537-1-1	MHH533	3720.00	3540.00	914.00 B	2910.00
22	537-2-1	MHH526	5590.00	4440.00	370.00 B	3230.00
23	529-1-1	MHH525	6360.00	6830.00	673.00 B	4400.00
24	527-2-1	MHH530	1740.00	4050.00	160.00 B	2990.00
25	517-1-1	MHH504	339.00 B	753.00 B	337.00 B	1770.00
26	513-1-1	MHH537	4910.00	3500.00	732.00	3230.00
27	513-2-1	MHH534	2900.00	4150.00	792.00 B	3010.00
28	509-3-1	MHH532	2190.00	3760.00	91.90 B	2560.00
28	509-3-1	MHH535	2080.00	3080.00	86.00 B	1870.00
29	509-1-1	MHH524	3240.00	4280.00	181.00 B	3660.00
30	505-2-1	MHH522	1610.00	2720.00	329.00 B	2510.00
31	505-3-1	MHH503	1460.00	1420.00	427.00 B	2370.00
32	505-4-1	MHH510	25800.00	6530.00	236.00 B	4490.00
33	501-1-1	MHH511	1660.00	2070.00	301.00 B	2150.00
34	488-1-1	MHH531	2350.00	2830.00	760.00 B	2080.00
35	486-1-1	MHH515	21700.00	2540.00	1000.00 B	2780.00
35	486-1-1	MHH519	20610.00	2160.00	1020.00 B	2580.00

U - none detected, amount reported is the instrument detection limit (IDL)
B - amount determined between the IDL and the contract required detection limit (CDL)
N - natural sample
N - spike recovery exceeds control limits
E - estimation due to interferences
+ - correlation coefficient < 0.995
* - duplicate exceeded control limits
J - estimate
R - unuseable data

Table . Total metals (suite 3) for the 35 bulk samples from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
TOTAL METALS III : HNO3/H2O2 Extract

Site Sample Number	Sample Name	ITR Number	Total Sb (mg/ kg)	Total Ba (mg/ kg)	Total Be (mg/ kg)	Total Co (mg/ kg)	Total Ni (mg/ kg)	Total Se (mg/ kg)	Total Ag (mg/ kg)	Total Tl (mg/ kg)	Total V (mg/ kg)
1	559-2-1	MHH509	23.00 N*J	276.00	0.41 B	4.10 U	4.30 U	0.80 UJ	33.20 N*J	1.10 B	22.20
2	559-3-1	MHH505	130.00 N*J	242.00	0.41 U	4.10 U	30.80	0.80 UJ	72.40 N*J	1.00 U	7.50 B
3	559-4-1	MHH506	25.30 N*J	105.00	0.40 U	4.00 U	4.20 U	0.80 UJ	77.20 N*J	1.00 U	3.20 U
4	556-3-1	MHH518	10.90 N*J	123.00	0.61 B	6.10 B	4.30 U	1.20 SJ	1.80 UN*J	1.00 U	69.90
5	556-1-1	MHH501	34.00 N*J	89.00	0.40 U	4.00 B	19.70	0.80 UJ	39.30 N*J	1.00 U	18.10
6	556-1-2	MHH502	30.40 N*J	167.00	0.81 B	7.70 B	29.80	0.80 UJ	1.80 UN*J	1.00 U	34.90
7	556-2-1	MHH513	10.90 UN*J	581.00	2.00	9.90 B	4.20 U	0.80 UJ	1.80 UN*J	1.00 U	267.00
8	553-1-1	MHH528	10.80 UNJ	127.00	1.20 J	6.00 B	3.70 U	0.80 UN*J	30.20 P	1.00 UNJ	71.70
9	553-1-2	MHH517	34.80 N*J	126.00	0.60 B	4.60 B	14.70	0.80 UJ	23.50 N*J	1.00 U	38.80
10	553-2-1	MHH521	11.00 UNJ	83.00	0.86 B	25.50	9.80	4.90 +N*J	0.71 U	1.00 U+NU	51.60
11	551-1-1	MHH520	10.90 UN*J	457.00	0.40 U	4.00 U	20.20	1.30 J	56.10 N*J	1.00 U	30.40
12	551-4-1	MHH508	11.10 UN*J	239.00	1.20	11.30 J	14.40	0.80 UJ	1.80 UN*J	1.00 U	46.80
13	551-2-1	MHH512	10.80 UN*J	104.00	0.60 B	4.00 B	4.20 U	0.80 UJ	1.80 UN*J	1.00 U	64.10
14	551-3-1	MHH529	48.50 NJ	452.00	1.00	6.50 B	3.80 U	2.40 N*J	51.50	1.00 U+NUJ	43.70
15	547-1-1	MHH536	10.90 UNJ	101.00	1.30	7.30 B	4.20 B	0.80 UN*J	8.70	1.00 UNJ	89.30
16	547-2-1	MHH523	52.10 NJ	208.00	1.20 J	8.60 B	3.80 U	0.80 UN*J	58.00	1.00 UNJ	36.20
17	543-2-1	MHH527	11.00 UNJ	68.20	1.40	7.70 B	4.40 B	1.00 BN*J	0.72 U	1.00 UNJ	63.60
18	543-4-1	MHH516	12.80 N*J	384.00	0.41 B	4.30 B	4.30 B	1.60 +J	21.50 N*J	1.00 U	35.10
19	541-3-1	MHH507	11.10 UN*J	312.00	0.41 U	4.30 B	13.60	0.80 UJ	6.60 N*J	1.00 U	30.20
20	541-4-1	MHH514	10.90 UN*J	127.00	0.40 U	5.00 B	4.20 U	0.80 UJ	1.00-UN*J	1.00 U	40.60
21	537-1-1	MHH533	41.70 NJ	433.00	1.00	7.20	4.30 B	1.90 SN*J	73.40	1.00 USNJ	46.70
22	537-2-1	MHH526	25.40 NJ	419.00	1.40	9.80 B	5.40 B	0.80 UN*J	41.20	1.30 NJ	48.20
23	529-1-1	MHH525	13.30 NJ	390.00	2.50	12.30	7.80 B	0.90 UN*J	24.10	1.00 UNJ	70.50
24	527-2-1	MHH530	21.20 NJ	254.00	1.40	8.10 B	4.00 B	1.90 +N*J	28.20	1.00 UNJ	52.90
25	517-1-1	MHH504	11.00 UN*J	126.00	0.41 U	4.10 B	4.30 U	1.10 UJ	1.80 UN*J	1.00 U	46.40
26	513-1-1	MHH537	11.00 UNJ	197.00	1.00	7.80	7.50 B	0.90 BN*J	30.60	1.00 UNJ	24.80
27	513-2-1	MHH534	24.60 NJ	273.00	1.00	7.80 B	19.10 U	0.80 UN*J	15.30	1.00 UNJ	31.20
28	509-3-1	MHH532	18.80 NJ	129.00	4.90	9.70 B	7.80 B	0.80 UN*J	8.80	1.00 UNJ	29.90
28	509-3-1	MHH535	10.90 UNJ	103.00	6.60	8.50 B	5.20 B	0.80 UN*J	8.30	1.00 UNJ	26.00
29	509-1-1	MHH524	11.00 UNJ	257.00	1.00	12.60	9.70	0.80 UN*J	0.71 U	1.00 UNJ	65.20
30	505-2-1	MHH522	10.90 UNJ	187.00	1.00	6.80 B	3.70 U	0.80 UN*J	5.20	1.00 UNJ	59.80
31	505-3-1	MHH503	11.00 UN*J	127.00	0.41 U	4.70 B	4.30 U	0.80 UJ	1.80 UN*J	1.00 U	29.20
32	505-4-1	MHH510	11.30 UN*J	278.00	0.63 B	5.60 B	18.10	0.80 UJ	1.90 UN*J	1.00 U	25.90
33	501-1-1	MHH511	11.00 UN*J	150.00	0.41 B	4.10 U	4.30 U	0.80 UJ	1.80 UN*J	1.00 U	36.20
34	488-1-1	MHH531	10.90 UNJ	128.00	1.40	7.00 B	6.30 B	0.80 UN*J	0.71 U	1.00 UNJ	40.40
35	486-1-1	MHH515	11.60 UN*J	184.00	0.43 U	5.80 B	4.50 U	1.70 +J	1.90 UN*J	1.10 U	44.40
35	486-1-1	MHH519	11.50 UN*J	168.00	0.42 U	4.20 U	4.50 U	4.90 +J	1.90 UN*J	1.10 U	36.50

U - none detected, amount reported is the instrument detection limit (IDL)
B - amount determined between the IDL and the contract required detection limit (CRDL)
N - natural sample
S - determined by method of standard

N - spike recovery exceeds control limits
E - estimation due to interferences
+ - correlation coefficient < 0.995
* - duplicate exceeded control limits
J - estimate
R - unuseable data

Table . Ammonium acetate extractable metal levels in bulk samples from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
EXTRACTABLE METALS : NH4OAc Extract

Site Sample Number	Type	ITR Number	Extr. Al (mg/ kg)	Extr. Cd (mg/ kg)	Extr. Cu (mg/ kg)	Extr. Fe (mg/ kg)	Extr. Mn (mg/ kg)	Extr. Pb (mg/ kg)	Extr. B (mg/ kg)	Extr. Zn (mg/ kg)
1	559-2-1 N	3538H-77	24.10	1.16	386.00	16.20	194.00	17.00	0.25	239.00
2	559-3-1 N	3538H-76	1.52 B	3.21	910.00	44.80	128.00	173.00	0.20	1710.00
3	559-4-1 N	3538H-75	21.80	0.56	61.60	36.60	15.60	4.48	0.30	177.00
4	556-3-1 N	3538H-60	24.40	0.32	411.00	13.40	10.80	4.74	0.21	64.00
5	556-1-1 N	3538H-69	11.60	1.00	2080.00	11.80	303.00	181.00	0.18	251.00
6	556-1-2 N	3538H-70	31.40	2.41	2050.00	6.78	234.00	1560.00	0.28	367.00
7	556-2-1 N	3538H-66	24.20	0.12	27.70	49.50	17.40	0.90 S	0.18	22.00
8	553-1-1 N	3538H-50	38.20	0.37	56.50	30.90	40.10	2.50 S	0.12	86.60
9	553-1-2 N	3538H-59	11.60	1.89	786.00	6.24	175.00	1390.00	0.10 U	331.00
10	553-2-1 N	3538H-49	153.00	0.21	97.70	665.00	36.10	0.06	0.10 U	40.60
11	551-1-1 N	3538H-62	70.30	1.40	498.00	96.60	429.00	0.13 S	0.14	415.00
12	551-4-1 N	3538H-68	4.22	15.30	766.00	5.69	783.00	42.80	0.10 U	1600.00
13	551-2-1 N	3538H-67	56.60	0.16	24.10	31.10	15.40	0.78 S	0.16	39.60
14	551-3-1 N	3538H-54	20.70	1.17	1130.00	104.00	245.00	110.00	0.10 U	315.00
15	547-1-1 N	3538H-82	61.90	0.20	56.10	27.40	13.90	0.86	0.19	45.10
16	547-2-1 N	3538H-55	9.53	3.37	857.00	28.90	979.00	629.00	0.62	465.00
17	543-2-1 N	3538H-53	42.20	0.05	12.90	61.40	11.00	1.25	0.10 U	11.60
18	543-4-1 N	3538H-61	40.40	1.85	2110.00	118.00	191.00	0.26 S	0.17	568.00
19	541-3-1 N	3538H-78	7.68	3.37	674.00	80.10	1140.00	0.20 U	0.26	789.00
20	541-4-1 N	3538H-65	23.60	0.96	196.00	15.50	78.40	0.37	0.18	252.00
21	537-1-1 N	3538H-79	10.80	6.27	1320.00	82.10	1960.00	17.00	0.24	1420.00
22	537-2-1 N	3538H-52	12.30	5.93	1890.00	27.60	905.00	426.00	0.25	992.00
23	529-1-1 N	3538H-56	25.10	4.88	1470.00	11.70	644.00	8.26	0.15	812.00
24	527-2-1 N	3538H-51	38.10	3.99	473.00	24.90	163.00	5.33	0.18	1180.00
25	517-1-1 N	3538H-71	19.10	0.10	14.00	268.00	12.50	0.25 S	0.10 U	29.10
26	513-1-1 N	3538H-81	89.40	0.70	237.00	156.00	64.50	3.98	0.10 U	121.00
27	513-2-1 N	3538H-80	25.40	5.24	484.00	14.10	260.00	725.00	0.32	648.00
28	509-3-1 N	3538H-84	14.50	5.88	197.00	3.36	65.50	511.00	0.18	345.00
29	509-1-1 N	3538H-58	5.50	2.48	74.50	0.64	30.10	2.21	0.10 U	132.00
30	505-2-1 N	3538H-57	40.20	0.19	76.90	90.50	22.60	0.28 S	0.10 U	30.30
31	505-3-1 N	3538H-73	464.00	1.01	326.00	304.00	83.10	0.02 U	0.10 U	195.00
32	505-4-1 N	3538H-72	5.32	4.69	149.00	0.69 B	12.90	2.42	1.74	297.00
33	501-1-1 N	3538H-74	122.00	0.84	201.00	124.00	119.00	0.39 S	0.16	155.00
35	486-1-1 N	3538H-63	66.30	0.61	111.00	341.00	59.70	0.10 U	0.10 U	87.20

U - none detected, amount reported is the instrument detection limit (IDL)
B - amount determined between the IDL and the contract required detection limit (CRDL)
N - natural sample
S - determined by method of standard addition (MSA)
N - spike recovery exceeds control limits
E - estimation due to interferences
+ - correlation coefficient < 0.995
* - duplicate exceeded control limits
J - estimate
R - unuseable data

Table . Saturation extract (soluble) and ammonium acetate extractable major cations from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
MAJOR CATIONS: Soluble & Extractable

Site Sample Number	Type	ITR Number	Extr. Ca (mg/kg)	Extr. Mg (mg/kg)	Extr. Na (mg/kg)	Extr. K (mg/kg)	Sol. Ca (mg/kg)	Sol. Mg (mg/kg)	Sol. Na (mg/kg)	SATN. Nitrate (%)	Nitrate (mg/kg)	Extr. P (mg/kg)	Total P (mg/kg)	HCL Extr. As (mg/kg)
1	559-2-1	N	3538H-77	1390.00	87.00	48.30	69.60	276.912	36.615	49.740	57.57	0.80 B	22.00	646.00 F
2	559-3-1	N	3538H-76	607.00	42.90	6.04	6.00	159.630	32.076	0.488	37.56	0.50 B	55.00	255.00 F
3	559-4-1	N	3538H-75	232.00	33.30	46.70	8.00	132.056	28.417	57.113	27.86	0.50 B	32.00	58.80 F
4	556-3-1	N	3538H-60	436.00	98.20	159.00	34.70	104.008	25.671	103.707	30.06	0.50 B	25.00	108.00 F
5	556-1-1	N	3538H-69	1140.00	38.50	62.80	20.00	122.672	19.362	48.473	27.08	1.70	21.00	793.00 F
6	556-1-2	N	3538H-70	1420.00	120.00	120.00	99.00	166.518	21.025	74.681	33.64	0.60	10.40	225.00 F
7	556-2-1	N	3538H-66	490.00	47.40	53.50	14.00	127.211	25.115	45.491	27.24	0.50 B	14.00	194.00 F
8	553-1-1	N	3538H-50	99.20	8.53	9.30	19.50	4.917	0.489	1.833	24.71	0.80	19.00	432.00 F
9	553-1-2	N	3538H-59	223.00	12.20	8.79	13.30	29.027	1.981	2.690	26.63	1.00	5.90	633.00 F
10	553-2-1	N	3538H-49	2440.00	140.00	10.10	9.00	138.172	121.110	0.710	27.97	0.50 B	18.00	79.80 F
11	551-1-1	N	3538H-62	240.00	114.00	42.60	19.30	211.048	101.921	50.548	102.95	0.60	77.00	1860.00 F
12	551-4-1	N	3538H-68	7450.00	363.00	48.00	262.00	453.196	64.311	29.344	81.51	2.80	19.00	28.50 F
13	551-2-1	N	3538H-67	49.80	5.16	8.97	19.50	6.219	0.802	2.469	26.13	1.00	22.00	287.00 F
14	551-3-1	N	3538H-54	2820.00	71.80	57.10	19.20	361.289	56.653	65.647	76.87	0.50 B	36.00	1810.00 F
15	547-1-1	N	3538H-82	156.00	6.87	10.60	29.30	32.057	1.669	3.176	29.96	2.10	8.90	328.00 F
16	547-2-1	N	3538H-55	1560.00	625.00	332.00	202.00	153.462	466.752	289.598	35.36	0.50 B	8.40	488.00 F
17	543-2-1	N	3538H-53	117.00	9.80	11.90	9.00	54.833	4.540	4.451	29.48	0.50 B	3.40	253.00 F
18	543-4-1	N	3538H-61	4080.00	174.00	304.00	40.30	254.016	70.308	229.068	56.70	0.50 B	29.00	1210.00 F
19	541-3-1	N	3538H-78	2050.00	69.30	66.70	12.00	205.920	34.389	50.193	51.48	0.60	60.00	1080.00 F
20	541-4-1	N	3538H-65	238.00	26.60	13.60	17.00	74.171	8.375	4.961	24.56	0.50 B	17.00	280.00 F
21	537-1-1	N	3538H-79	2320.00	422.00	282.00	27.40	292.052	420.005	299.281	72.29	1.10	46.00	1450.00 F
22	537-2-1	N	3538H-52	2920.00	201.00	77.20	181.00	289.948	63.407	50.541	61.56	0.50 B	16.00	664.00 F
23	529-1-1	N	3538H-56	3530.00	372.00	295.00	195.00	245.531	157.207	196.647	55.55	55.00	8.20	426.00 F
24	527-2-1	N	3538H-51	116.00	38.40	16.90	73.20	21.138	8.309	5.812	43.05	4.30	11.00	283.00 F
25	517-1-1	N	3538H-71	89.90	27.30	8.57	8.00	60.662	19.096	1.615	42.72	0.50 B	12.00	57.20 F
26	513-1-1	N	3538H-81	2540.00	70.10	45.80	52.60	176.998	20.928	19.332	36.27	3.30	20.00	200.00 F
27	513-2-1	N	3538H-80	1110.00	202.00	422.00	309.00	107.866	36.101	228.825	62.35	130.00	16.00	146.00 F
28	509-3-1	N	3538H-84	563.00	83.90	9.27	214.00	9.418	1.767	1.215	22.37	3.00	33.00	160.00 F
29	509-1-1	N	3538H-58	1160.00	167.00	27.10	365.00	13.234	2.667	4.357	41.10	9.60	14.00	71.90 F
30	505-2-1	N	3538H-57	411.00	29.90	22.80	16.00	77.984	6.649	14.197	49.99	2.80	13.00	174.00 F
31	505-3-1	N	3538H-73	915.00	199.00	7.35	6.00	185.504	173.680	0.632	40.77	0.50 B	24.00	212.00 F
32	505-4-1	N	3538H-72	8550.00	664.00	71.10	565.00	353.126	60.058	26.819	66.88	0.60	5.80	21.80 F
33	501-1-1	N	3538H-74	600.00	140.00	24.10	17.00	204.531	82.848	12.643	43.15	0.50	18.00	188.00 F
35	486-1-1	N	3538H-63	15100.00	121.00	29.70	6.00	197.447	76.458	11.805	42.01	0.50 B	11.00	180.00 F

U - none detected, amount reported is the instrument detection limit (IDL)

B - amount determined between the IDL and the contract required detection limit (CRDL)

N - natural sample

S - determined by method of standard addition (MSA)

N - spike recovery exceeds control limits

E - estimation due to interferences

+ - correlation coefficient < 0.995

* - duplicate exceeded control limits

J - estimate

R - unuseable data

Table . Soluble metal levels from a saturation extract from the 35 bulk sample sites in the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
SOLUBLE METALS : Saturation Extract

Site Sample Number	Type	ITR Number	Sol. AL (mg/kg)	Sol. Cd (mg/kg)	Sol. Cr (mg/kg)	Sol. Cu (mg/kg)	Sol. Fe (mg/kg)	Sol. Mn (mg/kg)	Sol. Pb (mg/kg)	Sol. B (mg/kg)	Sol. Zn (mg/kg)	Sol. As (mg/kg)
1	559-2-1 N	3538H-77	6.045	0.405	0.002 U	60.448	0.012 B	95.566	0.058 J*	0.282 P	113.413	0.049 SJ*
2	559-3-1 N	3538H-76	5.258	2.655	0.001 U	908.952	10.254	125.075	0.080 J*	0.018	1900.536	0.073 J*
3	559-4-1 N	3538H-75	30.367	0.546	0.019	62.685	13.568	16.187	0.025 J*	0.012	188.891	0.490 J*
4	556-3-1 N	3538H-60	4.659 J*	0.082 J*	0.001 U	61.623 J*	0.553 J*	3.186 J*	0.009 J*	0.077	22.274 J*	0.004 J*
5	556-1-1 N	3538H-69	1.660 J*	0.371 J*	0.001 U	176.562 J*	0.007 BJ*	174.937 J*	0.131 J*	0.034	137.566 J*	0.032 SJ*
6	556-1-2 N	3538H-70	0.116	0.118	0.001 B	3.361	0.054	22.707	0.111 J*	0.067	27.652	0.006 J*
7	556-2-1 N	3538H-66	23.127 J*	0.060 J*	0.006	15.854 J*	1.896 J*	12.639 J*	0.006 J*	0.065	15.527 J*	0.010 SJ*
8	553-1-1 N	3538H-50	0.415 J*	0.019 J*	0.001 U	1.581 J*	0.376 J*	2.340 J*	0.053 J*	0.020	5.066 J*	0.030 J*
9	553-1-2 N	3538H-59	0.019 BJ*	0.228 J*	0.001 U	9.560 J*	0.038 J*	27.429 J*	0.865 J*	0.025	48.733 J*	0.006 J*
10	553-2-1 N	3538H-49	241.381 J*	0.141 J*	0.324	108.244 J*	528.633 J*	34.123 J*	0.004 J*	0.003 U	42.235 J*	0.814 J*
11	551-1-1 N	3538H-62	91.214 J*	1.277 J*	0.009 B	384.004 J*	1.822 J*	442.685 J*	0.002 UJ*	0.132	457.098 J*	0.684 J*
12	551-4-1 N	3538H-68	0.073 BJ*	0.222 J*	0.002 U	0.314 J*	0.021 BJ*	105.148 J*	0.002 UJ*	0.293	65.371 J*	0.002 J*
13	551-2-1 N	3538H-67	1.529 J*	0.024 J*	0.001 B	2.119 J*	0.055 J*	2.490 J*	0.002 J*	0.032	6.297 J*	0.005 J*
14	551-3-1 N	3538H-54	29.211 J*	0.853 J*	0.003 B	689.524 J*	38.589 J*	251.365 J*	0.087 J*	0.142	325.929 J*	0.102 J*
15	547-1-1 N	3538H-82	4.584	0.046	0.001 B	8.239	0.124	3.895	0.002 J*	0.044	12.344	0.011 J*
16	547-2-1 N	3538H-55	0.240 J*	0.446 J*	0.001 U	1.871 J*	0.001 UJ*	427.856 J*	0.224 J*	0.213	75.670 J*	0.005 J*
17	543-2-1 N	3538H-53	26.031 J*	0.028 J*	0.006	7.960 J*	3.980 J*	6.633 J*	0.007 J*	0.047	8.078 J*	0.004 J*
18	543-4-1 N	3538H-61	37.932 J*	0.856 J*	0.002 U	844.830 J*	5.148 J*	103.194 J*	0.034 J*	0.291	314.685 J*	0.090 J*
19	541-3-1 N	3538H-78	15.959	1.616	0.002 U	285.714	0.210	694.980	0.036 J*	0.113	476.705	0.067 SJ*
20	541-4-1 N	3538H-65	9.554 J*	0.336 J*	0.002 B	49.611 J*	0.142 J*	31.191 J*	0.004 J*	0.042	105.362 J*	0.005 J*
21	537-1-1 N	3538H-79	33.976	4.121	0.002 U	719.286	1.793	1850.624	0.026 S+R*	0.262	1337.365	0.123 SJ*
22	537-2-1 N	3538H-52	1.761 J*	1.539 J*	0.005 B	188.374 J*	0.113	351.508 J*	0.979 J*	0.122	365.051 J*	0.017 J*
23	529-1-1 N	3538H-56	4.366 J*	1.267 J*	0.005 B	142.763 J*	0.065 J*	240.531 J*	0.023 J*	0.119	299.414 J*	0.012 J*
24	527-2-1 N	3538H-51	6.070 J*	0.908 J*	0.001 U	57.257 J*	0.123 J*	42.447 J*	0.020 J*	0.007	322.014 J*	0.006 J*
25	517-1-1 N	3538H-71	51.264	0.065	0.052	14.183	221.290	9.441	0.025 J*	0.004 U	26.358	0.013 J*
26	513-1-1 N	3538H-81	26.949	0.198	0.004	51.866	0.918	24.156	0.004 J*	0.075	44.249	0.011 SJ*
27	513-2-1 N	3538H-80	5.917	0.396	0.002 U	9.353	0.552	50.940	0.985 J*	0.124	104.125	0.054 J*
28	509-3-1 N	3538H-84	0.251	0.087	0.001 U	0.904	0.149	1.734	0.244 J*	0.026	7.561	0.047 J*
29	509-1-1 N	3538H-58	0.637 J*	0.009 J*	0.001 U	0.261 J*	0.670 J*	0.393 J*	0.075 J*	0.037	1.019 J*	0.111 J*
30	505-2-1 N	3538H-57	6.349 J*	0.043 J*	0.003 B	12.997 J*	0.835 J*	5.299 J*	0.007 J*	0.093	7.848 J*	0.005 J*
31	505-3-1 N	3538H-73	689.013	0.844	0.097	297.621	30.904 J	80.725	0.001 *	0.004 U	200.588	0.060 J*
32	505-4-1 N	3538H-72	0.208	0.003 B	0.002 B	0.120	0.141	0.029	0.001 UJ*	0.143	0.160	0.037 J*
33	501-1-1 N	3538H-74	95.361	0.475	0.003 B	96.656	1.761	78.102	0.011 J*	0.060	109.169	0.008 SJ*
35	486-1-1 N	3538H-63	144.514 J*	0.286 J*	0.040	66.376 J*	47.891 J*	43.270 J*	0.006 J*	0.037	65.115 J*	0.017 J*

U - none detected, amount reported is the instrument detection limit (IDL)
B - amount determined between the IDL and the contract required detection limit (CRDL)
N - natural sample
S - determined by method of standard addition (MSA)
N - spike recovery exceeds control limits
E - estimation due to interferences
+ - correlation coefficient < 0.995
* - duplicate exceeded control limits
J - estimate
R - unuseable data

Table . Physical and chemical data for the 35 bulk samples from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
PHYSICAL/CHEMICAL DATA

Site Sample Number	Sample Name	Type	ITR Number	Depth (in)	Satn. Extr. pH	Satn. Extr. EC (mmhos/ cm)	Cation Exchange Capacity (meq/100g)	Organic Matter (%)	Rock (%)	Sand (%)	Silt (%)	Clay (%)	Saturation Percentage (%)
1	559-2-1	N	3538H-77	0 to 15	4.20	2.80	18.00	2.10	4.50	63.10	25.00	12.00	57.57
2	559-3-1	N	3538H-76	5 to 21	3.80	6.70	14.00	0.16	0.50	46.60	43.70	9.80	67.56
3	559-4-1	N	3538H-75	0 to 15	2.70	4.90	9.40	0.33	0.20	84.20	10.50	5.20	27.86
4	556-3-1	N	3538H-60	0 to 15	4.30	2.80	14.00	1.30	12.80	83.70	11.30	5.00	30.06
5	556-1-1	N	3538H-69	0 to 13	4.40	4.00	26.00	0.99	5.20	81.40	13.00	5.70	27.08
6	556-1-2	N	3538H-70	13 to 28	6.60	2.70	20.00	1.60	14.10	65.50	27.20	7.30	33.64
7	556-2-1	N	3538H-66	0 to 15	3.30	2.90	13.00	1.20	32.60	86.00	8.50	5.50	27.24
8	553-1-1	N	3538H-50	0 to 15	4.10	0.35	13.00	0.73	19.20	85.60	7.90	6.60	24.71
9	553-1-2	N	3538H-59	20 to 35	5.80	1.20	12.00	0.95	19.20	82.20	13.00	4.80	26.63
10	553-2-1	N	3538H-49	0 to 8	2.30	7.70	16.00	1.70	1.40	69.50	19.40	11.10	27.97
11	551-1-1	N	3538H-62	0 to 6	3.40	3.50	18.00	3.30	3.10	34.50	35.10	30.40	102.95
12	551-4-1	N	3538H-68	2 to 17	6.80	2.50	39.00	4.70	2.40	36.80	38.80	24.30	81.51
13	551-2-1	N	3538H-67	0 to 15	3.80	0.48	13.00	0.62	19.70	89.60	6.00	4.40	26.13
14	551-3-1	N	3538H-54	0 to 15	3.60	4.10	24.00	6.10	0.30	28.60	68.10	3.30	76.87
15	547-1-1	N	3538H-82	0 to 15	3.80	0.97	14.00	0.81	19.10	88.40	7.60	4.00	29.96
16	547-2-1	N	3538H-55	0 to 13	6.10	7.00	18.00	2.50	0.10	66.50	26.10	7.40	35.36
17	543-2-1	N	3538H-53	2 to 12	3.10	1.80	15.00	6.20	13.30	90.00	6.70	3.30	29.48
18	543-4-1	N	3538H-61	0 to 15	3.20	5.30	25.00	3.90	2.50	42.60	38.80	18.60	56.70
19	541-3-1	N	3538H-78	0 to 15	3.50	5.00	23.00	3.10	0.20	42.90	38.00	19.10	51.48
20	541-4-1	N	3538H-65	0 to 15	3.70	2.60	14.00	1.30	19.10	82.80	12.00	5.20	24.56
21	537-1-1	N	3538H-79	0 to 15	3.70	7.50	27.00	3.30	0.10	33.80	45.40	20.80	72.29
22	537-2-1	N	3538H-52	34 to 49	4.60	3.70	29.00	4.40	1.00	32.30	44.80	22.90	61.56
23	529-1-1	N	3538H-56	0 to 12	4.50	4.20	30.00	5.40	0.10	24.20	48.40	27.30	55.55
24	527-2-1	N	3538H-51	0 to 15	3.70	1.60	22.00	2.90	0.50	63.30	26.20	10.50	43.05
25	517-1-1	N	3538H-71	0 to 8	2.50	3.70	15.00	1.30	0.20	78.90	16.00	5.10	42.72
26	513-1-1	N	3538H-81	0 to 15	3.50	2.80	24.00	2.80	1.80	66.80	20.70	12.50	36.27
27	513-2-1	N	3538H-80	0 to 6	4.40	3.00	30.00	4.50	5.20	46.50	36.00	17.50	62.35
28	509-3-1	N	3538H-84	0 to 8	4.60	5.40	18.00	1.20	19.00	74.60	15.10	10.30	22.37
29	509-1-1	N	3538H-58	0 to 8	5.30	0.33	21.00	3.10	3.20	58.60	26.60	14.80	41.10
30	505-2-1	N	3538H-57	0 to 15	3.40	1.30	22.00	2.60	4.00	66.10	22.20	11.80	49.99
31	505-3-1	N	3538H-73	0 to 15	2.80	7.00	22.00	2.50	0.10	62.70	22.90	14.40	40.77
32	505-4-1	N	3538H-72	12 to 27	7.40	2.30	32.00	4.80	1.80	40.30	39.00	20.70	66.88
33	501-1-1	N	3538H-74	0 to 13	3.40	3.80	22.00	2.60	4.40	67.10	20.30	12.60	43.15
35	486-1-1	N	3538H-63	0 to 6	2.70	4.50	26.00	4.90	1.30	48.70	33.40	17.90	42.01

U - none detected, amount reported is the instrument detection limit (IDL)

B - amount determined between the IDL and the contract required detection limit (CRDL)

N - natural sample

S - determined by method of standard addition (MSA)

N - spike recovery exceeds control limits

E - estimation due to interferences

+ - correlation coefficient < 0.995

* - duplicate exceeded control limits

J - estimate

R - unuseable data

Table . Sulfur fractionation by the acid-base account method and active acidity in the 35 bulk samples from the Silver Bow Creek / STARS project.

STARS: Streambank Tailings and
Revegetation Study
Silver Bow Creek RI/FS
SULFUR FRACTIONS: Acid-base account

Site Sample Number	Type	ITR Number	Water Extractable S (%)	HCL Extractable S (%)	HNO3 Extractable S (%)	Residual S (%)	Total Neutralization S (%)	Potential (tons CaCO3/ 1000 t. soil)	SMP ABA Lime Req. (tons / acre)	LIME RATE w/o NP (t/ac)	ABA RATE w/ NP (t/ac)
1	559-2-1 N	3538H-77	0.330	0.130	0.230	0.024	0.720	12.50	10.41	19.56	7.06
2	559-3-1 N	3538H-76	0.760	0.380	1.080	0.370	2.600	31.60	13.68	53.17	21.57
3	559-4-1 N	3538H-75	0.180	0.030	0.220	0.054	0.480	0.10	2.22	9.55	9.45
4	556-3-1 N	3538H-60	0.210	0.130	0.450	0.022	0.810	33.60	10.41	26.44	-7.16
5	556-1-1 N	3538H-69	0.400	0.300	0.520	0.098	1.320	40.00	8.77	29.55	-10.45
6	556-1-2 N	3538H-70	0.170	0.010	0.090	0.029	0.290	41.50	2.22	5.18	-36.32
7	556-2-1 N	3538H-66	0.210	0.160	0.270	0.015	0.660	1.50	20.23	31.08	29.58
8	553-1-1 N	3538H-50	0.040	0.120	0.110	0.019	0.290	2.70	10.41	15.66	12.96
9	553-1-2 N	3538H-59	0.050	0.170	0.240	0.050	0.510	10.40	3.85	13.92	3.52
10	553-2-1 N	3538H-49	2.530	0.010	5.480	0.034	7.850	0.10	41.53	212.93	212.83
11	551-1-1 N	3538H-62	0.450	0.120	0.240	0.026	0.840	0.90	33.34	42.65	41.75
12	551-4-1 N	3538H-68	0.220	0.010	0.070	0.036	0.330	72.30	3.85	6.19	-66.11
13	551-2-1 N	3538H-67	0.090	0.020	0.130	0.027	0.270	4.10	10.41	14.77	10.67
14	551-3-1 N	3538H-54	0.490	0.290	0.520	0.038	1.340	4.80	34.98	55.61	50.81
15	547-1-1 N	3538H-82	0.100	0.090	0.140	0.018	0.340	18.60	16.96	22.69	4.09
16	547-2-1 N	3538H-55	0.320	0.010	0.920	0.104	1.340	32.30	0.58	29.48	-2.82
17	543-2-1 N	3538H-53	0.250	0.220	0.100	0.019	0.600	0.10	41.53	47.98	47.88
18	543-4-1 N	3538H-61	0.640	0.210	0.240	0.026	1.120	11.30	39.89	50.56	39.26
19	541-3-1 N	3538H-78	0.720	0.310	0.170	0.023	1.220	24.00	30.06	40.05	16.05
20	541-4-1 N	3538H-65	0.170	0.070	0.240	0.059	0.530	13.60	12.04	20.60	7.00
21	537-1-1 N	3538H-79	0.880	0.210	0.260	0.024	1.370	18.30	34.98	46.28	27.98
22	537-2-1 N	3538H-52	0.300	0.160	0.110	0.020	0.590	0.30	25.15	31.00	30.70
23	529-1-1 N	3538H-56	0.460	0.080	0.180	0.027	0.750	19.10	26.79	33.62	14.52
24	527-2-1 N	3538H-51	0.030	0.100	0.130	0.038	0.300	15.70	26.79	32.36	16.66
25	517-1-1 N	3538H-71	0.630	0.170	0.700	0.032	1.530	0.10	20.23	44.67	44.57
26	513-1-1 N	3538H-81	0.480	0.190	0.140	0.019	0.820	11.00	34.98	42.22	31.22
27	513-2-1 N	3538H-80	0.110	0.010	0.040	0.020	0.190	5.50	20.23	21.63	16.13
28	509-3-1 N	3538H-84	0.016	0.009	0.010	0.016	0.051	5.70	10.41	10.86	5.16
29	509-1-1 N	3538H-58	0.008	0.011	0.007	0.017	0.043	4.20	7.13	7.51	3.31
30	505-2-1 N	3538H-57	0.120	0.290	0.090	0.021	0.520	2.50	28.42	35.61	33.11
31	505-3-1 N	3538H-73	0.630	0.520	0.250	0.025	1.430	0.10	44.80	60.46	60.36
32	505-4-1 N	3538H-72	0.220	0.010	0.010	0.018	0.260	0.10	-4.34	-3.88	-3.98
33	501-1-1 N	3538H-74	0.350	0.310	0.130	0.019	0.810	7.80	34.98	43.72	35.92
35	486-1-1 N	3538H-63	2.080	0.790	0.200	0.026	3.100	0.10	49.72	67.90	67.80

U - none detected, amount reported is the instrument detection limit (IDL)
B - amount determined between the IDL and the contract required detection limit (CRDL)
N - natural sample
S - determined by method of standard addition (MSA)
N - spike recovery exceeds control limits
E - estimation due to interferences
+ - correlation coefficient < 0.995
* - duplicate exceeded control limits
J - estimate
R - unuseable data

APPENDIX B

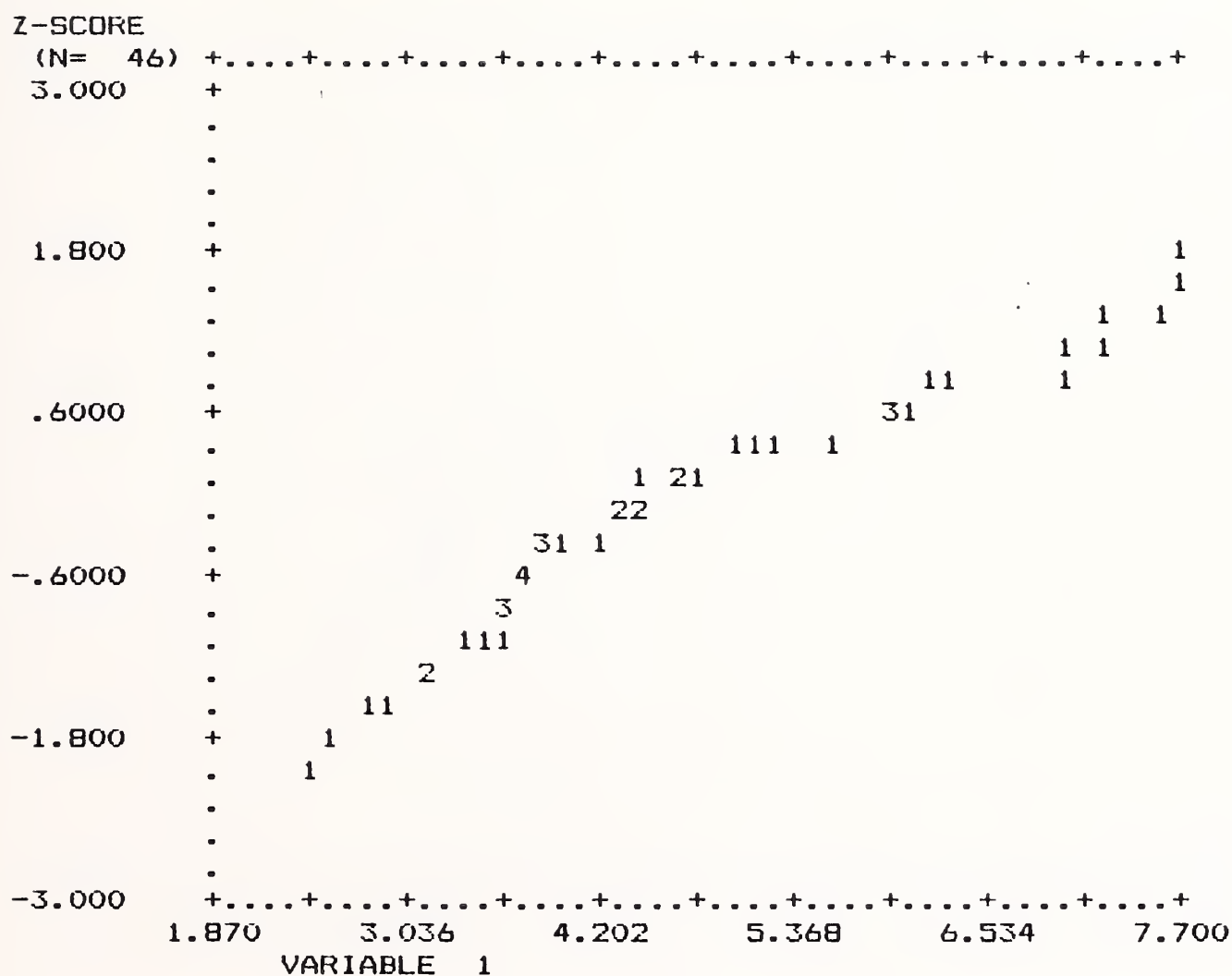
Data Normality/Z Scores

Data Normality/Z Scores

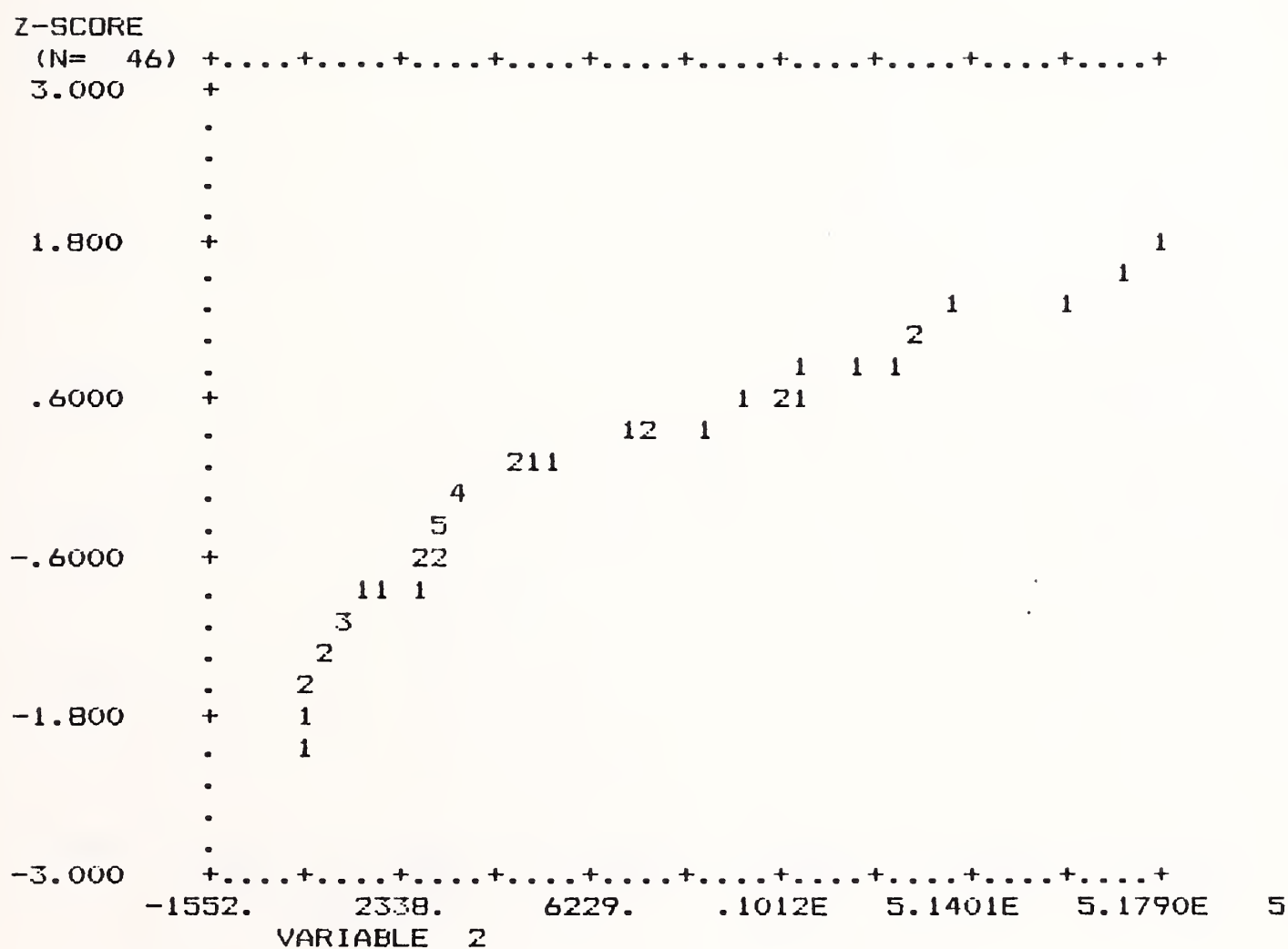
Phase 1 Silver Bow Creek RI Tailings data (Multitech, 1987)

cases = 46

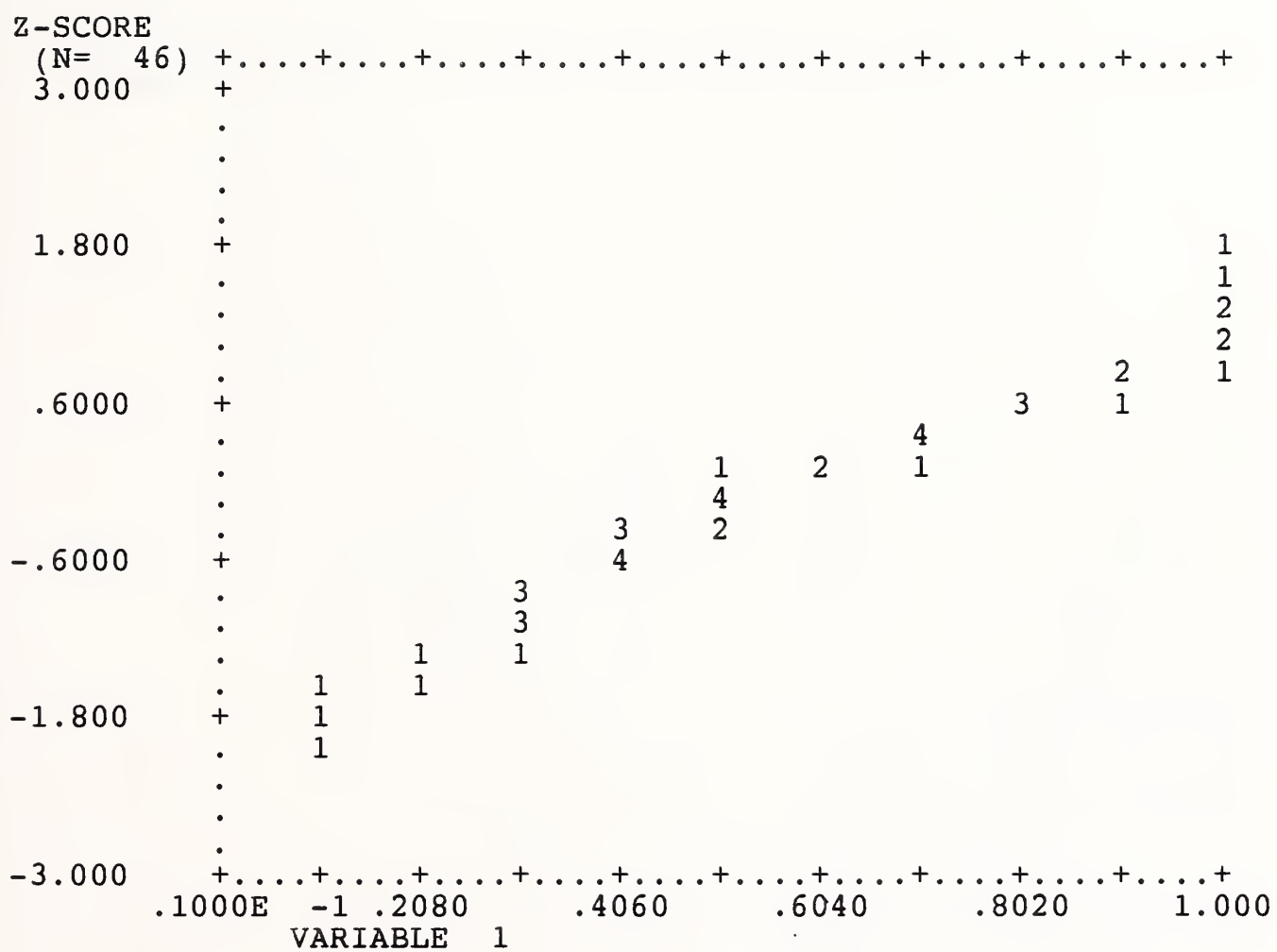
VARIABLE	MEAN	STANDARD DEVIATION	SKEWNESS	KURTOSIS
pH	4.73	1.49	.58	2.23
EC	5860	4917	.85	2.62
Rock + Sand	56.3	28.1	.20	1.89
Silt	34.4	34.4	-.21	1.74



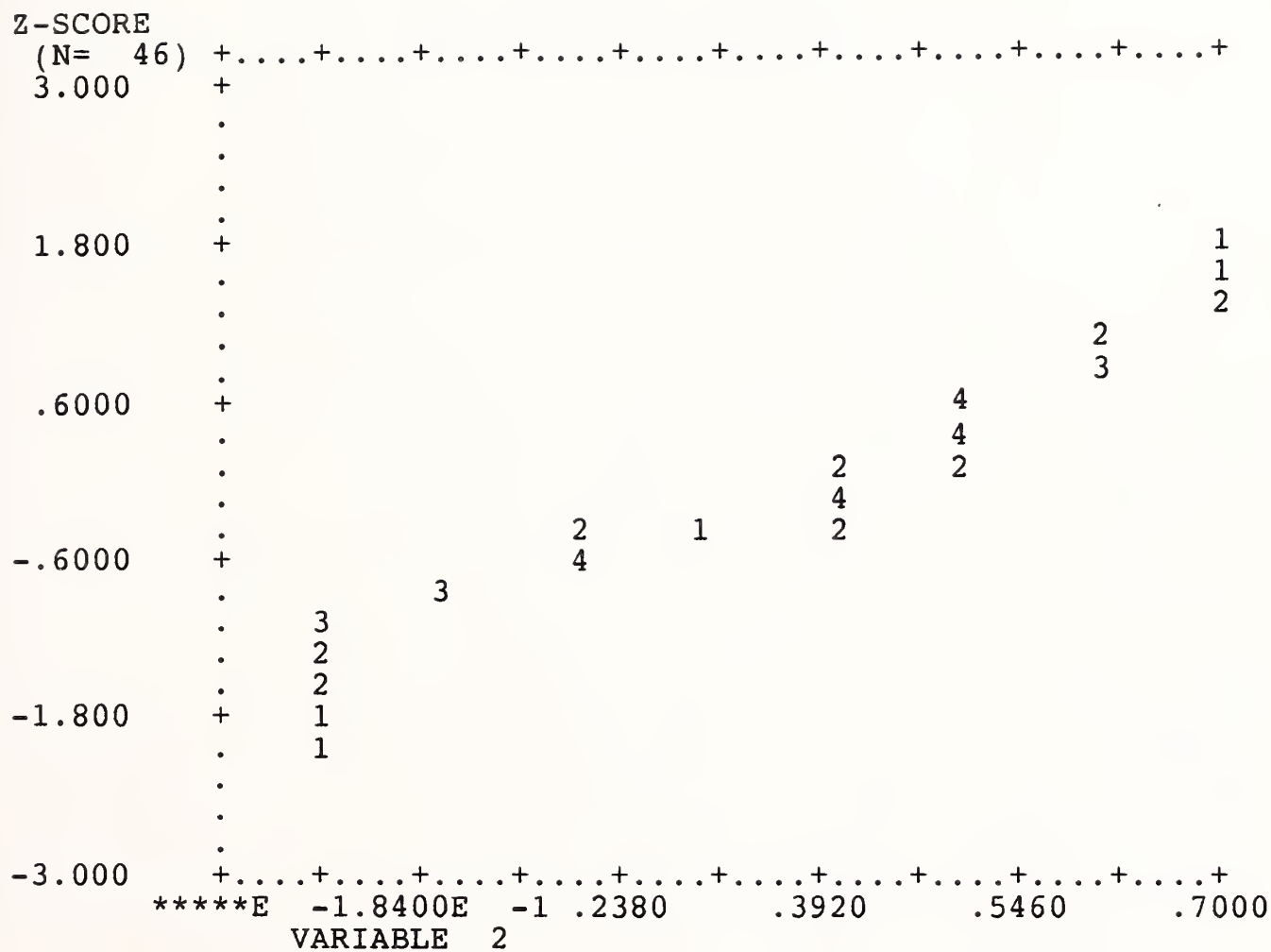
SOIL pH



ELECTRICAL CONDUCTIVITY ($\mu\text{mhos/cm}$)



ROCK + SAND (%)



APPENDIX C
SAS PRINCOMP Procedure

SAS PRINCOMP Procedure

VARIABLE NUMBER	VARIABLE
1	Sand (%)
2	Silt (%)
3	Clay (%)
4	Rock (%)
5	Moist color value
6	Moist color chroma
7	Average depth (in)
8	Log sulfate (mg/kg)
9	pH
10	Electrical conductivity (umhos/cm)
11	Moist consistence
12	Log total sulfur (mg/kg)

PRINCIPAL COMPONENT ANALYSIS

46 OBSERVATIONS
12 VARIABLES

SIMPLE STATISTICS

	V1	V2	V3	V4	V5	V6
MEAN	54.5717	35.9522	9.55870	12.6652	4.23913	4.04348
ST DEV	27.9570	23.2448	7.71859	18.1599	0.99297	2.22068

	V7	V8	V9	V10	V11	V12
MEAN	16.7283	3.41304	4.73043	5860.30	2.34783	3.66391
ST DEV	13.5977	0.73139	1.48741	4917.22	0.97108	0.68687

CORRELATIONS

	V1	V2	V3	V4	V5	V6
V1	1.0000	-0.9702	-0.6809	-0.7242	-0.1904	0.2925
V2	-0.9702	1.0000	0.4920	-0.7396	-0.2316	-0.3308
V3	-0.6809	0.4920	1.0000	-0.4008	0.0935	-0.0709
V4	-0.7242	-0.7396	-0.4008	1.0000	0.3155	0.4864
V5	-0.1904	-0.2316	0.0935	0.3155	1.0000	0.4285
V6	0.2925	-0.3308	-0.0709	0.4864	0.4285	1.0000
V7	-0.2459	0.2529	0.0795	-0.0711	-0.3991	-0.4636
V8	-0.4466	0.4528	0.2606	-0.2134	0.0507	-0.0154
V9	-0.4085	0.4470	0.0911	-0.3682	-0.4685	-0.4256
V10	-0.4166	0.4176	0.2558	-0.3383	-0.0566	-0.1491
V11	-0.1873	0.1889	0.1045	-0.0764	0.0040	0.1474
V12	0.1745	-0.1243	-0.2439	0.0299	0.1866	0.2055

	V7	V8	V9	V10	V11	V12
V1	-0.2459	-0.4466	-0.4085	-0.4166	-0.1873	0.1745
V2	0.2529	0.4528	0.4470	0.4176	0.1889	-0.1243
V3	0.0795	0.2606	0.0911	0.2558	0.1045	-0.2439
V4	-0.0711	-0.2134	-0.3682	-0.3383	-0.0764	0.0299
V5	-0.3991	0.0507	-0.4685	-0.0566	0.0040	0.1866
V6	-0.4636	-0.0154	-0.4256	-0.1491	0.1474	0.2055
V7	1.0000	0.2190	0.4447	-0.0303	0.1420	-0.3171
V8	0.2190	1.0000	-0.0106	0.7132	0.2719	0.3567
V9	0.4447	-0.0106	1.0000	-0.1628	0.1371	-0.3835
V10	-0.0303	0.7132	-0.1628	1.0000	0.1911	0.4128
V11	0.1420	0.2719	0.1371	0.1911	1.0000	-0.0107
V12	-0.3171	0.3567	-0.3835	0.4128	-0.0107	1.0000

PRINCIPAL COMPONENT ANALYSIS

	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
PRIN1	4.15850	1.74392	0.346542	0.34654
PRIN2	2.41458	1.04423	0.201215	0.54776
PRIN3	1.37035	0.18890	0.114196	0.66195
PRIN4	1.18145	0.35509	0.098455	0.76041
PRIN5	0.82636	0.28084	0.068863	0.82927
PRIN6	0.54552	0.02171	0.045460	0.87473
PRIN7	0.52382	0.17740	0.043651	0.91838
PRIN8	0.34641	0.02825	0.028868	0.94725
PRIN9	0.31816	0.13311	0.026514	0.97376
PRIN10	0.18506	0.05705	0.015421	0.98918
PRIN11	0.12801	0.12623	0.010667	0.99985
PRIN12	0.00177	.	0.000148	1.00000

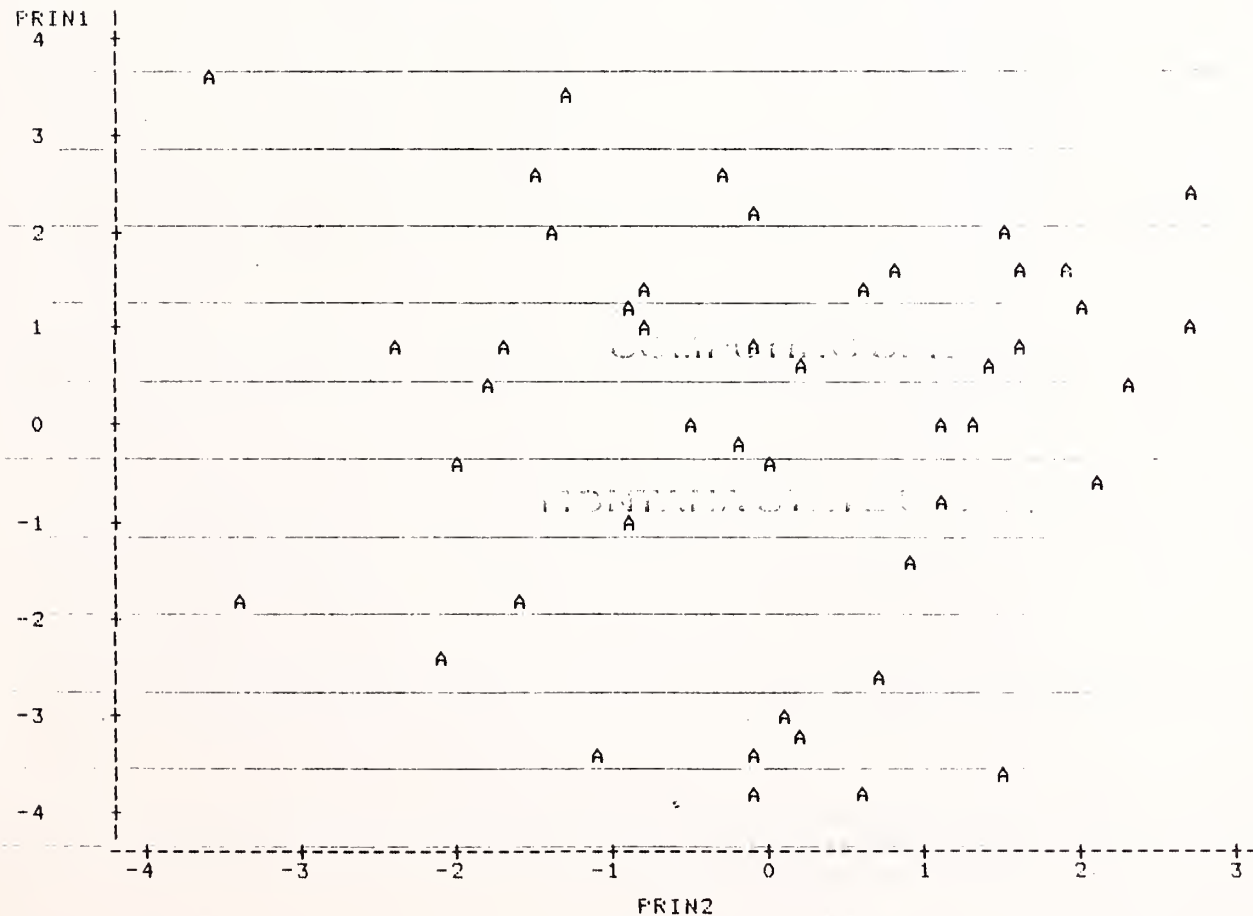
EIGENVECTORS

	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6
V1	-.452273	-.097687	0.236695	0.043874	0.019539	-.149688
V2	0.447616	0.080586	-.123819	-.055920	-.120632	0.263336
V3	0.279539	0.137876	-.514100	-.011909	0.311375	-.265497
V4	-.386421	-.019282	0.042238	0.351680	0.334288	0.116060
V5	-.200350	0.320066	-.402452	0.057174	0.245724	0.282767
V6	-.263754	0.275833	-.310273	0.289731	-.229453	0.314629
V7	0.218786	-.286732	0.274963	0.398533	0.509217	0.088835
V8	0.241227	0.408860	0.255425	0.243956	0.274999	0.261401
V9	0.274870	-.369797	0.041396	0.151471	-.262053	0.492865
V10	0.231733	0.439867	0.295305	-.063906	0.098867	-.317912
V11	0.116312	0.134691	-.015997	0.711574	-.459903	-.387798
V12	-.095043	0.433935	0.417497	-.179239	-.196088	0.273400

	PRIN7	PRIN8	PRIN9	PRIN10	PRIN11	PRIN12
V1	0.093000	0.009705	0.194798	-.281905	0.137158	0.748463
V2	-.018143	-.178484	-.364030	0.320709	-.164328	0.629467
V3	-.171164	0.474903	0.412645	-.001741	-.056069	0.206472
V4	-.216268	-.171224	0.212865	0.586274	-.366701	0.006201
V5	0.696685	-.128707	0.002351	0.033496	0.220090	-.018459
V6	-.561632	0.054254	-.163691	-.129275	0.400438	0.016287
V7	0.044348	0.327098	-.334108	0.040019	0.382067	0.011202
V8	-.082763	-.180798	0.112999	-.559324	-.374785	-.009690
V9	0.074371	-.058121	0.632682	0.034452	0.202618	0.003966
V10	-.111123	-.379101	0.240236	0.272387	0.512513	0.006508
V11	0.274365	0.084574	-.018722	0.052657	-.119296	-.002841
V12	0.110360	0.632266	0.066313	0.251592	-.058194	0.003726

PLOT OF THE FIRST TWO PRINCIPAL COMPONENTS

PLOT OF PRIN1*PRIN2 LEGEND: A = 1 OBS, B = 2 OBS, ETC.



APPENDIX D

SAS - Average Linkage Cluster Method

SAS - AVERAGE LINKAGE CLUSTER METHOD

Root-Mean-Square Total Sample Standard Deviation = 1555

Root-Mean-Square Distance Between Observations = 6954

AVERAGE LINKAGE CLUSTER ANALYSIS EIGENVALUES OF THE COVARIANCE MATRIX

	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
1	24179308	24178055	0.999940	0.99994
2	1252.91	1118.53	0.000052	0.99999
3	134.376	80.7194	0.000006	1.00000
4	53.6565	49.5834	0.000002	1.00000
5	4.0731	2.53934	0.000000	1.00000
6	1.53375	0.827969	0.000000	1.00000
7	0.905783	0.439429	0.000000	1.00000
8	0.466354	0.179149	0.000000	1.00000
9	0.287206	0.113374	0.000000	1.00000
10	0.173832		0.000000	1.00000

ROOT-MEAN-SQUARE TOTAL-SAMPLE STANDARD DEVIATION = 1555.22
ROOT-MEAN-SQUARE DISTANCE BETWEEN OBSERVATIONS = 6954.24

NUMBER OF CLUSTERS	CLUSTERS JOINED	FREQUENCY OF NEW CLUSTER	NORMALIZED CLUSTER DISTANCE
45	0338 0839	2	0.002114
44	0321 0822	2	0.004194
43	0330 0331	2	0.004773
42	0345 0846	2	0.005104
41	086 089	2	0.005507
40	081 082	2	0.007579
39	0336 CL42	3	0.008353
38	0814 0815	2	0.009054
37	CL40 0832	3	0.012357
36	0824 0837	2	0.014003
35	033 0819	2	0.014988
34	0818 0820	2	0.015123
33	CL38 CL39	3	0.015297
32	035 CL41	3	0.015791
31	0825 0835	2	0.016158
30	0811 CL43	3	0.017472
29	084 CL45	3	0.019572
28	0310 CL33	6	0.020291
27	0826 0844	2	0.020763
26	088 0841	2	0.027730
25	0840 0843	2	0.029105
24	CL35 0830	3	0.030834
23	0833 0834	2	0.037887
22	CL26 0812	3	0.044166
21	CL29 CL36	5	0.049895
20	CL32 CL31	5	0.055852
19	CL24 CL28	1	0.056065
18	CL34 CL25	4	0.066909
17	CL37 CL19	14	0.085713
16	0313 CL44	3	0.086535
45	0338 0839	2	0.002114
44	0321 0822	2	0.004194
43	0330 0331	2	0.004773
42	0345 0846	2	0.005104
41	086 089	2	0.005507
40	081 082	2	0.007579
39	0336 CL42	3	0.008353
38	0814 0815	2	0.009054
37	CL40 0832	3	0.012357
36	0824 0837	2	0.014003
35	033 0819	2	0.014988
34	0818 0820	2	0.015123
33	CL38 CL39	3	0.015297
32	035 CL41	3	0.015791
31	0825 0835	2	0.016158
30	0811 CL43	3	0.017472
29	084 CL45	3	0.019572
28	0310 CL33	6	0.020291
27	0826 0844	2	0.020763
26	088 0841	2	0.027730
25	0840 0843	2	0.029105
24	CL35 0830	3	0.030834
23	0833 0834	2	0.037887
22	CL26 0812	3	0.044166
21	CL29 CL36	5	0.049895
20	CL32 CL31	5	0.055852
19	CL24 CL28	1	0.056065
18	CL34 CL25	4	0.066909
17	CL37 CL19	14	0.085713
16	0313 CL44	3	0.086535

NUMBER OF CLUSTERS	CLUSTERS JOINED	FREQUENCY OF NEW CLUSTER	NORMALIZED RMS DISTANCE
15	CL27	4	0.090408
14	CL21	10	0.110600
13	OB28	2	0.119772
12	OB17	2	0.129565
11	CL16	4	0.135714
10	OB16	5	0.158383
9	CL17	15	0.176930
8	CL12	3	0.245951
7	CL22	5	0.252954
6	CL9	10	0.280558
5	CL11	9	0.342238
4	CL6	29	0.419994
3	CL7	14	0.583063
2	CL3	17	1.002871
1	CL4	46	1.377145

COMPUTING SERVICE

[illegible]

APPENDIX E

SAS Canonical Discriminant Analysis

SAS Canonical Discriminant Analysis

46 observations	45 DF Total
4 variables	43 DF Within Classes
3 Classes	2 DF Between Classes

SUMMARY STATISTICS

VARIABLE	MEAN	TOTAL S.D.	WITHIN CLASS S.D.	BETWEEN CLASS S.D.
pH	4.73	1.49	1.39	0.73
EC	5860	4917	4530	2588
Rocksand	56.4	27.6	10.7	31.0
Silt	34.6	22.9	9.0	25.6

CLASS MEANS

CLASS	pH	EC	ROCK + SAND	SILT
1	4.73	4572	73.6	20.3
2	3.57	2396	96.6	1.5
3	5.13	7604	35.3	52.2

BETWEEN CLASS DISTANCE MEASURE

CLASS	1	CLASS 2	3
-------	---	------------	---

Mahalanobis Distance

1	--	2.34	3.79
2	2.34	--	6.03
3	3.79	6.03	--

Probability of Significant Separation

1	--	0.0020	0.0001
2	0.0020	--	0.0001
3	0.0001	0.0001	--

CANONICAL CORRELATION

CANONICAL VARIATE	CANONICAL CORRELATION	ADJUSTED CANONICAL CORRELATION	APPROXIMATE STANDARD ERROR	CANONICAL CORRELATION SQUARED
1	0.932	0.927	0.020	0.869
2	0.204	0.102	0.143	0.041

CANONICAL VARIATE	EIGENVALUE	DIFFERENCE	PROPORTION
1	6.61	6.57	0.994
2	0.04		0.006

TESTS FOR LIKELIHOOD THAT THE CORRELATION IN CURRENT ROW AND ALL FOLLOWING ARE ZERO

CANONICAL VARIATE	LIKELIHOOD RATIO	F	NUMERATOR DF	DEMONIMATOR DF	P
1	0.126	18.1	8	80	0.0001
2	0.959	0.59	3	41	0.624

TOTAL CANONICAL STRUCTURE (correlation between variable and canonical variates)

VARIABLE	CANONICAL VARIATE		
	1	2	3
Ph	.404	.754	-.478
EC	.466	.089	.880
Rocksand	-.994	.0025	.049
Silt	.990	-.021	-.051

RAW CANONICAL COEFFICIENTS

VARIABLE	CANONICAL VARIATE		
	1	2	3
pH	.0113	.817	.0453
EC	.000032	.000125	.0000491
Rocksand	-.0542	-.0232	.149
Silt	.0498	-.0623	.173

VARIABLE	CANONICAL VARIATE		
	1	2	3
1	-1.69	.33	0
2	-3.95	-.25	0
3	2.08	-.05	0

Table . Levels of pH, EC, rock plus sand, and silt; and canonical variates for samples from the phase 1 RI study for the Silver Bow Creek streambank tailings.

SAMPLE NUMBER	WASTE CLASS	pH	Electrical Conductivity (umhos/cm)	Rock+ Sand (%)	Silt (%)	----- CANONICAL VARIATES -----			
						1	2	3	4
1	1	3.7	3630	70.1	24.3	-2.43	.34	14.99	-1.76
2	2	4.2	3640	94.6	2.8	-4.82	1.52	14.95	-1.40
3	1	6	2990	88.7	8.4	-4.22	2.69	15.09	-1.81
6	2	3.4	352	96.6	.5	-5.16	.55	14.65	-1.93
7	1	3.2	906	74.8	19.5	-3.02	-.22	14.71	-2.16
8	2	2.9	1020	96.8	1.2	-5.12	.18	14.81	-1.78
9	3	4.4	2010	46.6	41.7	-.33	.17	14.46	-2.42
11	3	3.1	7210	25.4	38.3	.80	.46	10.90	-.75
12	2	3.8	984	96.3	2	-5.05	.87	14.92	-1.89
13	3	5	3150	34.6	52.2	.88	.42	14.57	-2.44
14	3	7	2880	14.5	63.3	2.54	1.80	13.57	-2.77
17	2	2.6	7030	94.3	2.7	-4.72	.65	14.98	-.55
18	1	2.4	12300	72.4	24.2	-2.29	.31	15.69	.07
19	2	2.8	3270	96.6	1.5	-5.02	.36	14.94	-1.32
20	2	4.4	3330	95.8	3	-4.89	1.60	15.16	-1.51
21	3	3.6	11500	43.6	39.4	.01	.91	14.04	-.29
22	3	3.7	17000	48.4	42.2	.07	1.40	15.51	.62
23	3	6	10600	44.5	46.8	.33	2.28	15.52	-1.00
24	3	7.2	3020	9.6	64.5	2.87	2.02	13.06	-2.72
26	1	3.7	10700	63.5	22.9	-1.91	1.46	14.12	-.17
27	3	3.6	12900	26.9	49.5	1.46	.85	13.37	-.11
28	3	3.8	12900	48.1	45.8	.13	.75	15.90	-.35
29	3	3.5	15800	34	54.8	1.44	.63	15.48	.15
33	2	4.3	627	99.1	0	-5.30	1.29	14.99	-1.98
34	2	3.7	1310	99.2	0	-5.29	.89	15.01	-1.79
37	3	3.6	5380	51.9	45.6	-.33	-.43	16.05	-1.91
38	3	5.3	13600	51.2	43.4	-.11	2.14	16.04	-.31
39	1	5.6	8500	78.6	15.9	-3.13	2.82	15.13	-.78
40	3	6.1	9330	30.5	56.7	1.54	1.91	15.09	-1.41
41	1	4	2760	59.4	35.6	-1.31	.02	15.33	-2.22
42	3	6.2	2780	41.7	50.9	.43	1.27	15.44	-2.70
44	3	6.3	3660	25.4	60.9	1.85	1.22	14.79	-2.64
48	3	7.2	4570	41.4	48.5	.40	2.47	15.11	-2.34
49	1	7.7	4830	69.6	23.7	-2.35	3.80	15.06	-1.86
52	3	3.8	1390	48.7	40.7	-.52	-.39	14.54	-2.49
53	1	5.9	3240	66.5	25.8	-2.15	2.08	14.80	-2.04
67	3	4.4	575	45.9	35.5	-.65	.39	13.21	-2.46
70	1	5.1	216	81.8	12.1	-3.77	1.54	14.52	-2.31
71	1	4.7	224	84.6	10.6	-4.00	1.24	14.66	-2.26
72	3	4.7	10300	43.1	48.2	.45	1.12	15.48	-.97
73	3	7.7	7400	37	50	.81	3.24	14.88	-1.80
82	3	4.3	17900	13.3	69.2	3.35	1.13	15.03	.30
83	3	3.6	10100	20.5	69.6	2.72	-.61	15.75	-1.34
88	3	4.8	5240	28.4	69.8	2.16	-.43	16.78	-2.58
89	3	7	3270	43	57	.69	1.58	16.75	-2.94
90	3	7.6	3250	18.9	71.2	2.71	1.74	15.64	-3.13

Table . Levels of pH, EC, rock plus sand, and silt; and canonical variates for samples from the STARS phase 2 RI bulk samples for the Silver Bow Creek streambank tailings.

SAMPLE NUMBER	WASTE CLASS	pH	Electrical Conductivity (umhos/cm)	Rock+ Sand (%)	Silt (%)	----- CANONICAL VARIATES -----			
						1	2	3	4
1	T	4.2	6700	64.69	24.27	-2.03	1.26	14.36	-1.09
2	T	3.8	6700	46.87	42.02	-.19	.24	14.75	-1.43
3	T	2.7	4900	84.23	10.1	-3.87	.24	14.66	-1.10
4	A	4.3	2800	85.55	7.79	-4.11	1.39	14.43	-1.61
5	A	4.4	4000	82.32	12.26	-3.67	1.42	14.78	-1.50
6	S	6.6	2700	69.76	27.2	-2.26	2.42	15.53	-2.33
7	B	3.3	2900	89.44	5.86	-4.42	.62	14.63	-1.49
8	B	4.1	350	87.92	7.05	-4.36	.91	14.52	-2.10
9	S	5.8	1200	85.07	13	-3.86	2.11	15.25	-2.27
10	A	2.3	7700	69.92	19.4	-2.55	.01	14.26	-.62
11	C	3.4	3500	36.47	35.1	-.08	.18	11.83	-1.60
12	S	6.8	2500	38.28	38.8	.02	2.56	12.85	-2.29
13	B	3.8	480	91.31	5.22	-4.63	.72	14.70	-2.03
14	C	3.6	4100	28.81	68.1	2.00	-1.46	16.44	-2.64
15	B	3.8	970	90.26	6.61	-4.49	.72	14.81	-1.97
16	A	6.1	7000	66.53	26.1	-2.01	2.69	15.05	-1.31
17	B	3.1	1800	91.17	5.15	-4.59	.32	14.70	-1.70
18	C	3.2	5300	44	38.8	-.25	-.16	13.67	-1.49
19	C	3.5	5000	43.01	37.25	-.28	.17	13.26	-1.50
20	A	3.6	2600	85.56	8.76	-4.08	.74	14.55	-1.62
21	C	3.7	7500	33.87	45.4	.71	.35	13.44	-1.17
22	S	4.6	3700	32.97	44.8	.62	.66	13.05	-1.98
23	C	4.5	4200	24.28	48.4	1.28	.62	12.40	-1.86
24	A	3.7	1600	63.48	26.2	-2.04	.12	14.24	-2.13
25	A	2.5	3700	78.94	16	-3.33	-.32	14.82	-1.46
26	F	3.5	2800	67.39	20.7	-2.49	.36	13.92	-1.72
27	F	4.4	3000	49.14	36	-.72	.59	13.90	-2.04
28	F	4.6	5400	78.66	15.1	-3.28	1.67	14.81	-1.28
29	A	5.3	330	59.88	26.6	-1.85	1.32	13.78	-2.49
30	A	3.4	1300	67.4	22.2	-2.47	-.01	14.10	-2.07
31	S	2.8	7000	62.74	22.9	-2.00	.28	13.78	-.82
32	C	7.4	2300	41.36	39	-.14	2.94	13.36	-2.45
33	A	3.4	3800	68.49	19.52	-2.58	.45	13.92	-1.49
35	C	2.7	4500	49.36	33.4	-.84	-.46	13.48	-1.49

APPENDIX F

Estimating Soil Texture

DETERMINING SOIL TEXTURE BY FEEL AND APPEARANCE

Soil is composed of individual particles that vary in size from several microns to several inches. The percentage of soil within each particlesize class defines the soil texture. Table F-1 illustrates the aprticle size classification developed by the USDA.

Table F-1. Size range of soil particle-size classes.

Particle-size Class	Diameter (mm)
Gravel	> 2mm
Sand	.05 - 2
Silt	.002 - .05
Clay	.002 mm

The soil texture is determined by plotting the percentage of each particle size class (neglecting particles greater than 2 mm) on the tri-linear diagram in Figure F-1. The percentage of material greater than 2 mm can be estimated by separating soil from gravels in a 2 mm sieve available from many equipment suppliers.

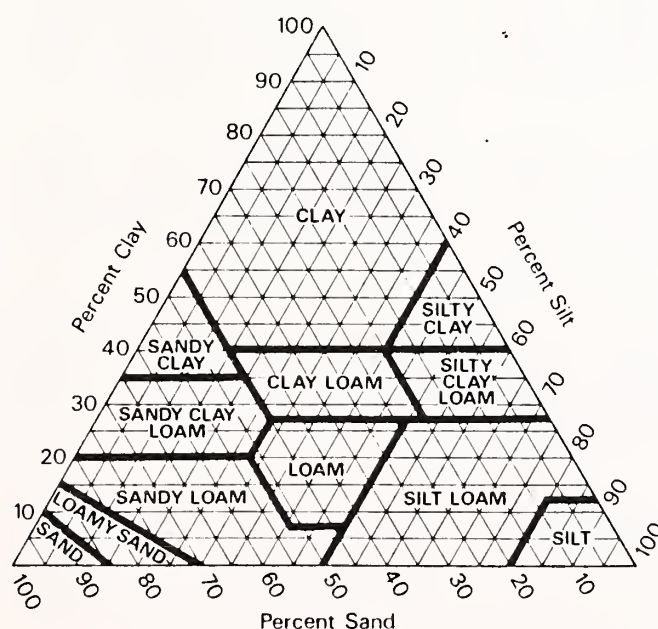


Figure F-1. The soil texture triangle for determining texture class from known percentages of sand, silt and clay.

Soil texture class can be estimated using the description in Table F-2 and the flow chart presented in Figure F-2. Then the approximate sand, silt, and clay content for the texture class can be inferred from the texture triangle in Figure F-1.

Table F-2. Verbal description of texture classes using the feel and appearance method.

Soil Textural Class	FEEL AND APPEARANCE OF SOIL	
	Dry Soil	Moist Soil
Sand	Loose, single grains which feel gritty. Squeezed in the hand, the soil mass falls apart when the pressure is released.	Squeezed in the hand it forms a cast which crumbles when lightly touched. Does not form a ribbon between thumb and forefinger. Very gritty
Loamy sand	Loose, single grains which feel gritty, but enough fine particles to stain finger-prints in palm of hand.	Squeezed in the hand it forms a cast which crumbles when touched and only bears very careful handling.
Sandy loam	Aggregates are easily crushed. Very faint velvety feeling initially, but as rubbing is continued, the gritty feeling of sand soon dominates.	Forms a cast which bears careful handling without breaking. Does not form a ribbon between thumb and forefinger.
Loam	Aggregates are crushed under moderate pressure; clods can be quite firm. When pulverized, loam has a velvety feel that becomes gritty with continued rubbing.	Cast can be handled quite freely without breaking. Very slight tendency to ribbon between thumb and forefinger. Rubbed surface is rough.
Silt loam	Aggregates are firm but may be crushed under moderate pressure. Clods are firm to hard. Smooth flour-like feel dominates when soil is pulverized.	Cast can be freely handled without breaking. Slight tendency to ribbon between thumb and forefinger. Rubbed surface has a broken or rippled appearance.
Silty clay loam	Aggregates are very firm. Clods are hard to very hard. Requires two hands to break them.	Cast can be handled very firmly without breaking. Tendency to ribbon between thumb and forefinger with some flaking; "greasy feeling", moderately sticky.
Clay	Aggregates are hard and clods are extremely hard, strongly resist crushing. Gritty feel when pulverized due to persistence of very tiny clay aggregates.	Forms a long, flexible ribbon, sticky when wet. Rubbed surface has very smooth, satin feeling.

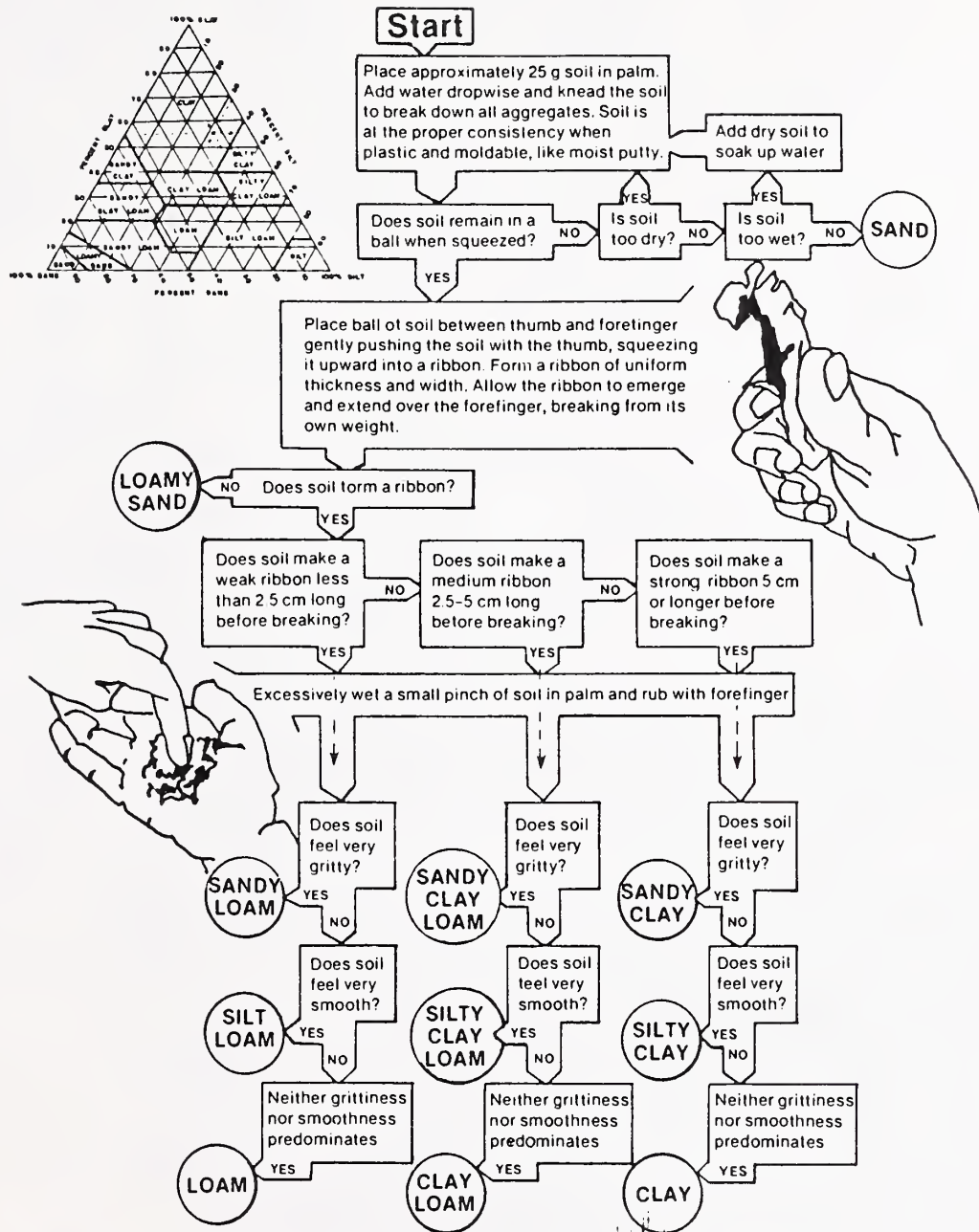


Figure F-2. Flow chart for determining soil texture class by the feel and appearance method.

